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Cantor Lectures

ON

THE MINING OF
NON-METALLIC MINERALS.

BY

BENNETT H. BROUGH, F.G.S., F.C.S., F.I.C.,

Associate of the Royal School of Mines; Member of Council of the Institution of
Mining Engineers.

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ARTS, MANUFACTURES & COMMERCE.

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SYLLABUS.

LECTURE I.

Coals and Bitumens.—Graphite—Coal—Brown coal—Peat—Petroleum—Ozokerite—Asphalt.

LECTURE II.

Salts.—Rock salt—Potash salts—Borates—Alums—Nitrates—Phosphates.

LECTURE III.

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LECTURE IV.

Precious Stones.—Diamond—Corundum gems—Emerald—Other precious stones—Ornamental stones
—Rare earths.

THE MINING OF NON-METALLIC MINERALS.

LECTURE I.—DELIVERED NOVEMBER 23, 1903.

Coals and Bitumens.—Graphite—Coal—Brown Coal—Peat—Petroleum—Ozokerite—Asphalt.

Three years ago I had the honour of giving a course of Cantor Lectures* on the nature and yield of metalliferous deposits, in which I reviewed the sources from which the world's supply of metals are obtained, and attempted to forecast the alterations which might be expected in the near future. It has been suggested that a similar course of lectures dealing with the supplies of the non-metallic minerals of economic importance would be of interest. The subject is undoubtedly one of great importance from a commercial point of view, as will be evident from a moment's consideration of the enormous value of the resources of non-metallic minerals. In the United Kingdom alone the value of the non-metallic minerals raised in 1901 was £111,000,000, while in the United States it was £113,000,000. In both cases it was considerably greater than the value of the metallic products. Moreover, with the advancement of science and technology, attention is constantly being devoted to new raw materials. Thus pitch-blende, the only mineral in which uranium occurs in appreciable quantities, serves for the production of a yellowish-green fluorescent glass, and is now eagerly sought for as the source of radium. Monazite, a silicate containing rare earths, was merely a scientific curiosity, until Auer von Welsbach introduced the incandescent mantle for gas lighting. Calcite is now

required for the polarisation apparatus for the sugar industry, mica in the electric industry, magnesite for lining open-hearth steel furnaces, china clay in paper manufacture, and phosphates as fluxes in iron smelting with the object of obtaining highly phosphatic slags for use in agriculture. These are a few examples of the constantly increasing field of usefulness for non-metallic minerals. The most important of all these are the combustible minerals, the coals and bitumens, with which I propose to deal this evening.

I.—THE COAL SERIES.

In the coal series are included a variety of hydro-carbons varying widely in properties. All have originated from the decomposition of plant growth in earlier geological periods. Peat is still in course of formation at the present time. The elementary composition of all these substances is much the same, and the gradual passage of woody tissue into graphite is shown by the following analytical results:—

	Carbon.	Hydrogen	Oxygen.
Wood	100	12·18	83·07
Peat	100	9·85	55·67
Lignite	100	8·37	42·42
Coal	100	6·12	21·23
Anthracite	100	2·84	1·74
Graphite	100	—	—

Graphite.—Graphite, plumbago, or black lead, as it is variously termed, is regarded by many authorities as the final product of

* *Journal of the Society of Arts*, vol. 48, pp. 673, 680, 705, 712.

alteration of plant remains. It occurs chiefly intercalated in the older crystalline metamorphic rocks, rarely sufficiently pure for it to be economically worked. The world's production of graphite in 1900 was as follows:—

	Metric tons.	Per cent. of total.
Austria	29,991	38.0
Ceylon	22,707	28.9
Italy	10,313	13.1
Germany	4,435	5.6
United States	3,000	3.8
Mexico	2,561	3.2
India	2,530	3.2
Sweden	1,783	2.2
Canada	1,307	1.7
Japan	94	0.2
World's total	78,721	100.0

The value of the world's production is estimated at £650,000.

The two principal centres of production are Austria, more particularly Southern Bohemia for the poorer grades, and Ceylon for the

FIG. 1.



GRAPHITE MINE NEAR HAGUE, NEW YORK.
(C. D. Walcott.)

coarse-grained best variety. Most of the Ceylon graphite contains more than 90 per cent. of carbon, whilst not more than a quarter of the Austrian output reaches that degree of purity. Of the districts of subordinate importance Piedmont in Italy and Passau in Bavaria are the most productive. The celebrated Borrowdale mines in Cumberland and the Alibert mine in Siberia have long ceased to be productive. In America, the chief deposits of

commercial value are in the State of New York. At Hague, Warren County, New York, the bed of graphite (Fig. 1) is nine feet thick and is formed of alternating layers of highly graphitic sandy shale and schist.

The purest varieties of graphite are used in the manufacture of pencils and as lubricants; the crystalline (Ceylon, Passau, Scandinavia) for crucibles, stove blacking, paints, and foundry facings. Artificial graphite now enters into competition with the natural product. The manufacture of artificial graphite, started at Niagara Falls a few years ago, continues to increase in importance. In 1901 there were made 1,125 tons, valued at £2 a ton. Half this output was used for the manufacture of electrodes.

Coal.—The word coal is a popular rather than a scientific term, being applied not only to beds of fossilised vegetation, but to any mineral substance capable of being used as fuel. The world's production of the various varieties of coal in 1901 exceeded 789,000,000 tons. It is difficult to realise what this vast amount means. Imagine it placed in 10-ton waggons along a railway line; the train would be 426,000 miles long. It would have to go seventeen times round the equator in order to hold a year's production of coal. The production of the various countries in 1901 was as follows:—

	Metric tons.	Per cent. of total.
United States	266,151,103	33.8
United Kingdom	222,562,123	28.2
Germany	153,019,414	19.4
Austria Hungary.....	40,757,895	5.1
France	32,325,302	4.0
Belgium	23,462,817	2.9
Russia	16,151,557	2.3
Japan	7,429,457	0.9
Australia	7,000,227	0.9
India	6,742,214	0.8
Canada	5,612,108	0.6
Spain	2,747,724	0.4
New Zealand	1,247,339	0.1
Other Countries	3,919,196	0.6
World's Total....	789,128,476	100.0

The outputs of the United States, the United Kingdom, and Germany combined, make up 81.4 per cent. of the world's production. The figures given include anthracite, bituminous coal, and brown coal. In 1902, the United States produced 268,688,000 tons, the United

Kingdom, 227,095,000 tons, and Germany, 107,436,000 tons. The production per head of population in the three countries was three and one-third tons, five and a-half tons, and two tons respectively.

Anthracite.—Anthracite is regarded as a coal, from which all the gas has been removed. It is hard, brittle, and lustrous, and burns with little flame and no smoke. Like other coals it occurs in beds usually of carboniferous age. The principal anthracite regions are in Eastern Pennsylvania and in South Wales, to the west of the Vale of Neath. The present annual output of these two regions is 50,000,000 and 2,000,000 tons respectively.

Bituminous Coal.—This term, a misleading one, is applied to coal which burns with a more or less smoky flame, and chemically occupies a place between brown coal and anthracite.

This field furnishes 66·7 per cent. of the total production of the United States. Next in importance are the portions of Illinois, Indiana, and Kentucky, which make up the central coalfield. This contributed 16·6 per cent. of the total output. The western coalfield furnished 8·7 per cent, the Rocky Mountain, 6·2 per cent., and the Pacific Coast, 1·2 per cent. In Germany, the Rhenish-Westphalian coalfield is the most extensive, whilst the largest in Europe is the Donetz coalfield in Russia.

The future of British coal mining is a matter for serious consideration. In 1840, Great Britain produced 75 per cent. of the world's supply of coal; at the present time it produces only 28 per cent. The condition of the iron trade has always exercised a most important influence on the production of coal, so that a large demand for iron draws with it a large

	Composition.			Coke yield per cent.	Sp. gr.
	Carbon.	Hydrogen.	O + N.		
1. Dry coal burning with long flame ..	75-80	4·5-5·5	15-19·5	50-60	1·25
2. Caking coal burning with long flame (gas coals)	80-85	5-5·8	10-14·2	60-68	1·28-1·3
3. Caking coal proper (furnace coal) ..	85-89	5-5·5	5·5-11	68-74	1·30
4. Caking coal burning with short flame (coking coal)	88-91	4·5-5·5	5·5-6·5	74-82	1·3-1·35
5. Lean or sandy coal burning with short flame	90-93	4-4·5	3-5·5	82-90	1·35-1·4
6. Anthracitic	93-95	2-4	3	over 90	1·6

“Flaming” was suggested by Percy as a good substitute for the word bituminous. For economic purposes he classed bituminous coals as (1) non-caking or free-burning, rich in oxygen, (2) caking, and (3) non-caking, rich in carbon. Gruner's researches led to the following classification:—

The passage from one class to another is gradual. The ash-forming constituents of coal vary from 0·5 to 30 per cent. Cannel coal is a variety of bituminous coal, rich in hydrogen, especially valuable as a gas coal. Coal is mined in the United Kingdom from beds of carboniferous age. The seams worked vary from 11 inches up to 30 feet in thickness. The great coal counties are Durham, Yorkshire, and Glamorganshire. Information regarding the occurrence of coal in Great Britain is given in E. Hull's “Coalfields of Great Britain.” In the United States the most important coalfields are those contained in the Appalachian mountain system, which extends from Pennsylvania and Ohio, to Alabama.

demand for mineral fuel. Statistics show, however, that since 1870 the world's production of pig iron has increased from 12,000,000 to 44,000,000 tons in 1902, but the share of Great Britain has fallen from 48·8 per cent. to 20 per cent. It cannot be denied that during the past quarter of a century its coal-mining industry has not developed so rapidly as that of its American and German commercial rivals. Great Britain, until 1899, held the first place.

It is interesting to note that, although coal was first mined as far back as the year 1113, by the monks of the Klosterrath Abbey at Kirchrath on the Wurm, it was in Great Britain that it was first used on a large scale, on the Tyne, the “coaly Tine” of Milton. In 1239, King Henry III. is said to have granted a charter to the townsmen of Newcastle-on-Tyne, for the raising of coal for fuel, and so early was their produce attracted to London, that by the beginning of the next century great complaint arose of the injury done by the coal

smoke to the health of the citizens. "The nice dames of London," says Stow, in 1598, "would not come into any house or room where sea-coals were burned." By the time of Charles I, the use of coal had become very general, and as the demand increased the price went up. In 1643, a pamphlet was published with the imprint "Printed in the year that sea-coal was exceeding dear." At the beginning of the 19th century, about 10,000,000 tons were raised annually in Great Britain. The continental production at that time was very small, the large expanse of forest land having delayed the necessity for turning to mineral fuel. Since then enormous strides have been made. At that period the machinery was of a primitive type. Even in 1837 a colliery was in operation in the county of Durham at which coals were raised by a donkey and banked out and sold by an old woman. Compare this with a modern pit raising 2,000 tons a day from a depth of a quarter of a mile. At Bolsover colliery 3,217 tons have been raised from a depth of 1,175 feet in nine hours, and a week's record at the Cambrian colliery, Clydach Vale, was 13,019 tons, raised from a depth of 1,350 feet. The literature of coal mining is so extensive that it is unnecessary here to enter into details of the remarkable improvement in the mechanical appliances used at collieries. Illustrations will be found in abundance in the standard work by Mr. Herbert W. Hughes, who gives some remarkable photographs taken by himself underground, showing the methods of mining in the 10-yard coal of South Staffordshire. Some very striking examples of machinery were shown in the mining building at Düsseldorf Exhibition last year. Among these must be mentioned the colossal winding engine built by the Prince Rudolph Ironworks at Dülmen for the Preussen colliery of the Harpener Company. It is a vertical 800 horse-power engine, designed by Tomson, to wind from a depth of 4,000 feet, and has two conical spiral drums 32 feet in greatest diameter and 11½ feet wide. The drums are not, as is the usual practice, placed side by side, but one behind the other, an arrangement that increases the safety and lessens the wear of the rope. Whilst for this engine, which created amazement by its vast size, steam was used as motive power, there was in the same building an electrically driven winding engine, made by the Friedrich Wilhelm works, of Mülheim, which showed that electric driving may now be applied with advantage on a large scale.

This engine, built for the Gelsenkirchen Company, raises 1,000 tons in six hours from a depth of 1,650 feet. The two electromotors are each of 1,400 horse-power. The absence of a winding drum is due to the fact that the Koepe system of winding with only one rope is employed. An interesting model showed the winding and coal-washing plant of the Emscher shaft of the Kölner Company. There was also shown a Riedler express pump with double acting plungers of 7¼ inch diameter and 9·8 inch stroke, making 200 revolutions per minute, and raising in that time 550 gallons of water from a depth of 1,970 feet. It was driven by an alternating motor made by the Helios Electricity Company of Cologne.

With the rapid rate of consumption, anxiety as to the duration of the British coalfields is well founded. Professor Hull estimates that the total quantity of coal within a depth of 4,000 feet still remaining is 81,683,000,000 tons. This estimate is reassuring, although it is not in accord with the less optimistic and divergent views on the question expressed by Professor Stanley Jevons, by the Right Honourable Leonard H. Courtney, by Mr. R. Price-Williams, by Mr. T. Forster Brown,* and by Lieut. C. W. Bellairs.† All these estimates are of slight value, owing to the impossibility of prophesying either the rate of increase in production and consumption, or the limits at which mining may be carried on with profit. Early in the last century, a shaft 100 feet in depth was an object of wonder, and a glance over the history of the depths hitherto attained, clearly shows the remarkably rapid progress that has been made in this respect. At the present time the greatest depth at which mining operations are carried on in Great Britain has been reached at the Pendleton colliery, near Manchester, where the deepest workings are nearly 3,500 feet below the surface. This enormous depth has, however, been exceeded in other countries, notably in the Lake Superior district, where the Red Jacket shaft of the Calumet and Hecla copper mine has now attained the record depth of 4,900 feet, and in Belgium, where a colliery at Mons is 3,937 feet deep.‡ Depths such as these show that the limit of depth of 4,000 feet adopted by Professor Hull and by the Royal Coal Commissioners in 1870, though ridiculed at the time, was well within the

* *Journal of the Society of Arts*, vol. 47, p. 506.

† *Ibid.*, vol. 49, p. 549.

‡ "Mining at Great Depths." By Bennett H. Brough *Journal of the Society of Arts*, vol. 45, p. 57.

bounds of possibility. In view of the marvellous efficiency of modern winding engines, no considerations of a mechanical nature need limit the prospective depths of shafts. By far the most important obstacle to very deep mining is the certain and proportionate increase of temperature according to depth. At the Paruschowitz borehole, in Silesia, the deepest in the world, put down by the Prussian Government to a depth of 6,573 feet, this increase of temperature with depth has been found to be 1° Fahrenheit for 62·1 feet. Taking this as a fair average, a coal seam at a depth of 4,000 feet would be, without the cooling action of an artificial ventilating current, 64° warmer than ground near the surface. Further information on these questions may be expected from the labours of the Royal Commission appointed, with terms of reference of a far-reaching character, on December 28, 1901. On August 5, 1903, they issued an interim report, offering no opinion nor recommendation, but containing much valuable evidence.

The questions of the possible economies in the use of coal and of the adoption of better methods of working should prove the most fruitful field for the labours of the Commission. In Great Britain more and more attention is being devoted to improvements in details of mining. Although the use of mechanical coal cutters has by no means become as general as it has in the United States, where 25 per cent. of the output is thus obtained, there has recently been a distinct increase in the use of these labour-saving appliances. Moreover, endeavours are being made to economise in the consumption of coal, notably in the South Staffordshire coalfield, where the producer-gas invented by Dr. Ludwig Mond, has recently been introduced as a cheap source of heat and power. That great economies in the home consumption of coal have been effected since 1871 is unquestionable. Indeed, Mr. Price-Williams has shown that, whereas in 1871 the iron and steel trade required 30 per cent. of the coal consumed in the United Kingdom, its requirements had been reduced to 16 per cent. at the time he read his paper before the Statistical Society in 1889. With improvements conducive to economy in fuel it is evident that a considerable industrial development may take place with a very slight increase in coal consumption.

From time to time important new discoveries of coal are made in various parts of the world. Coal, for example, has now been struck at Dover in the area described by Mr. W.

Whitaker.* In Belgium again, in that portion of the province of Antwerp known as the Campine, coal of excellent quality has recently been found, and it is estimated that this new field contains more than 500,000,000 tons of coal. In the British colonies and dependencies the production of coal increases year by year. In the eastern states of Australia there are some 62,000 square miles of coal-bearing country, and the coal resources of India have been shown by Professor W. R. Dunstan† to be enormous. There can, therefore, be no doubt that there are ample resources to meet all the demands for coal. Nevertheless, with a view to husbanding the British coal resources, the need for taking measures to avoid waste in mining is apparent. The great waste of small coal, though lessening year by year, is still a reprehensible extravagance. The more general use of coal-mining machines would tend to reduce this source of waste by furnishing a larger proportion of lump coal. There is, too, much needless waste in the consumption of coal, notably in the coal used for domestic purposes. Saving in this direction might give the country years of prosperity.

Brown Coal.—Under the general term of lignite or brown coal, Percy included those varieties of coal that form the intermediate stage between peat and true coals of carboniferous age. According to their geological age, brown coals have a distinct ligneous texture (true lignite, fibrous brown coal), or are without organic structure (earthy brown coal), or black and lustrous with conchoidal fracture. Brown coal burns with a very long smoky flame. It is largely used for heating steam boilers, evaporating pans, and for domestic purposes. The better qualities are sometimes used in Austria and Germany for metallurgical purposes. In Great Britain, brown coal has been worked only in a seam of lower tertiary age at Bovey Tracey in Devonshire. On the Continent, brown coal is extensively mined, the greatest production being shown by North-West Bohemia and the district of Halle in Prussia. In 1902, Bohemia with 36,074 miners raised 18,262,592 tons of brown coal, whilst the Halle district with 35,055 miners raised 29,233,936 tons in 1902. Besides this, the mines of the Cologne district raised 5,354,440 tons, the kingdom of Saxony, 1,635,000 tons, Upper Bavaria, 24,000 tons, and Styria in Austria, 2,585,233 tons. The beds of brown

* *Journal of the Society of Arts*, vol. 38, p. 543.

† *Ibid*, vol. 50, p. 371.

coal often attain considerable thickness, six to eight yards being not unusual. At Brühl, near Cologne, the brown-coal bed is in places as much as 340 feet thick. Most of the brown coal from this bed is compressed into briquettes for household use, the development of the industry having been greatly facilitated by the fact that the Rhine is available for transport. The proprietors of one of the mines in this district have had the enterprise to add to their equipment an electric central station, which by means of 50 miles of main cables, furnishes a large area with light and power. The brown coal, which is mined in open workings, is taken by electric haulage to seven boilers, the steam being used for engines that drive triphase generators yielding currents at 5,700 volts. Thick deposits of brown coal are found at various localities in the British colonies. At Lal Lal, in Victoria, for example, the beds are 150 feet thick, and are covered by basalt. At the Miranda Mine in New Zealand the seam is 55 feet thick.

Peat.—Peat or turf is the most recent product of the decay of plants under special conditions of air and moisture, either in swampy ground, actually under water, or in mountainous regions kept moist by fogs. It consists of the fossil remains of moss mixed with other plants. It may be classified (1) according to the localities where it has been formed as lowland and mountain peat; (2) according to its age, as recent peat with distinct vegetable structure, and old peat of a dark brown or black colour, with mere traces of organic texture; (3) according to the mode in which it has been extracted, as cut peat or dredge peat. Peat bogs are of frequent occurrence in all parts of the world. In Europe, the most considerable are in Russia, Ireland, Germany, Scandinavia, and Austria. In France, Italy, and Spain, peat is of less frequent occurrence. Air-dried peat is used for heating boilers, evaporating pans, pottery kilns, and for domestic purposes. Even when dried, peat cannot be economically substituted for coal on account of its bulky nature and consequent cost for carriage, its want of uniformity, and its large percentage of water and ash. Many well-directed efforts have been made of late years to utilise the material in the very extensive peat bogs of Ireland, Scandinavia, and elsewhere, by producing by compression or other treatment, a compact and useful fuel; and there can be no doubt that compressed peat will be more generally used when the cost of coal is much enhanced.

II.—THE BITUMEN SERIES.

Besides coal, there are a series of hydrocarbons occurring in various forms: as natural gas, liquid as petroleum, viscous as ozokerite, and solid as asphalt. There are too, gradations from one to another. Whilst coals appear to have been formed from the decomposition of plants, the bitumens are probably distillation products from organic matter of animal origin.

Natural Gas.—This subject has already been dealt with in papers by Prof. J. Dewar* and Mr. W. Topley†. In the petroleum districts of Pennsylvania and adjoining States, natural gas issues from the strata at a depth of 500 to 2,000 feet below the surface, and when boreholes are sunk to the accumulation, the gas rises under a mean pressure of 150 to 200 lbs. per square inch. When first reached, the tension of the gas is very high, 1,000 lbs. per square inch being not unusual. Since 1821, natural gas has been utilised in a limited way; but since the reading of Mr. Andrew Carnegie's paper on natural gas before the Iron and Steel Institute in 1885, it has attained an extraordinarily rapid development for industrial purposes. For generating steam, 1,000 cubic feet of gas is equal to 80 to 133 lbs. of coal. The neighbourhood of Pittsburg, in Pennsylvania, is the most important locality for natural gas. No record is kept of the production in the United States. The amount of coal, however, displaced by gas in 1901 was 8,458,600 tons. There were 10,297 wells producing, and there were 21,848 miles of natural gas mains, the gas being used in 1,545 industrial establishments. It has been found that the supply of gas in a reservoir is limited. Indeed, some have already been exhausted. On the other hand, a gas well in Ohio has been blowing for twenty years without any apparent diminution in the supply. Natural gas is also being produced on a commercial scale in England by the Natural Gas Fields of England, Limited (capital £100,000). It was discovered in west Sussex as long ago as 1836, and later discoveries induced the London, Brighton, and South Coast Railway Company to light Heathfield Station with natural gas. Bore holes were then sunk 300 to 400 feet through impervious sandstone and marl with successful results, and at Heathfield some 80 houses are now using natural gas for lighting and heating. It is burnt in the street lamps, and gas-engines are being driven by it. According to the

* *Journal of the Society of Arts*, vol. 33, p. 771.

† *Ibid.*, vol. 39, p. 421.

official statistics compiled for the Home Office by Sir C. Le Neve Foster the production of natural gas in 1902 was 150,000 cubic feet. Experimental borings are being made over 200 square miles of the county of Sussex, and if it can be proved that the Weald is underlain by a gasfield the industrial conditions of the south of England will be entirely changed.

Petroleum.—The subject of petroleum has already been exhaustively dealt with in a course of Cantor Lectures by Mr. Boverton Redwood,* and has since been discussed in papers read before the Society by Mr. R. D. Oldham,† Mr. G. Stockfleth,‡ and Sir Marcus Samuel.§ I need, therefore, deal but briefly with this industry which during the past 40 years has acquired such remarkable importance. It dates from the year 1859, when Colonel Edwin L. Drake bored at Titusville, Pennsylvania, the first oil well. The utilisation of the distillates of the crude oil, benzine and petroleum, and the heavy oils as residues, soon not only acquired important development in the United States, but furnished an important article of export. The still more important petroleum field of Baku, on the eastern side of the Caucasus on the Caspian Sea, where the occurrence of petroleum was described by Marco Polo in the 13th century, and where the existence of the eternal fires of the Apsheron peninsula has been known for 2,500 years, has been developed since 1870. The importance of the petroleum industry is best shown by the fact that some 20,000,000 tons are produced annually; of this the United States and Baku produce the bulk, Galicia, Roumania, Burma, the Dutch Indies, Japan, and Canada comparatively small quantities. The world's production of petroleum in 1901, was as follows:—

	Metric tons.	Per cent. of total.
Russia	9,827,822	49·2
United States	8,811,326	44·2
Austria-Hungary ...	407,958	2·0
Roumania	320,000	1·6
India	201,135	1·0
Dutch Indies	128,604	0·6
Japan	86,200	0·4
Canada	74,383	0·3
Germany	44,095	0·2
World's total ..	19,940,447	100·0

* *Journal of the Society of Arts*, vol. 34, pp. 805, 817, 830, 867, 883, 899, 915.

† *Ibid.*, vol. 42, p. 145.

‡ *Ibid.*, vol. 42, p. 676.

§ *Ibid.*, vol. 47, p. 384.

The residues, known in Russia as Mazout, compete in the oilfields with coal. They serve for heating locomotives and steam ships. The transport of the oil is noteworthy. For retail trade it is loaded in the well-known blue barrels or in rectangular tinplate cases. For transport on a large scale, tank steamers are used, and tank waggons on the railways, the loading and unloading being effected by pumping in pipe lines. Certainly, Drake's enterprise in 1859 marked an epoch in the history of mining. Compare the carriage of oil in barrels on waggons and in flat boats down the creek to the river, with the pipe-line transportation from the wells to the coast. Compare, too, the £4 a barrel paid for Drake's crude oil with the 4s. a barrel at the end of the century.

Being cheap and developing great heat on combustion, petroleum is largely used as fuel. The average calorific power of the crude oil is 10,000 calories. Various varieties give the following calorific powers, in calories:—West Virginia, heavy oil, 10,180; West Virginia, light oil, 10,223; Pennsylvania, light oil, 9,963; Ohio, heavy oil, 10,399; Java, 10,831; Roumania, 10,005; and Baku, 11,460. The recent development of the Texas oil fields has resulted in a great increase in the number of steamers, locomotives, and factories using oil fuel in the United States, whilst in South America, Peruvian oil has been largely used. The Borneo, Japan, and Sumatra oilfields are supplying large quantities for consumption in India, Japan, and Australia. No oil is so suitable for illumination as that of Pennsylvania. In many circumstances petroleum is a very economical fuel. It occupies less space than coal, a ton of coal occupying 40½ cubic feet, oil 33 cubic feet. It also presents the advantages of greater efficiency of evaporation per unit measure of heating surface, more equable generation of steam, greater cleanliness and freedom from ash, avoidance of heat caused by frequent opening of furnace doors, and instantaneous extinction of furnace fires.

The Russian supplies are the most extensive, the chief district being to the north of Baku on the Caspian. At the present time some 2,000 boring derricks are in operation, and during 1902 they raised 11,000,000 tons of crude petroleum. The bore-holes have an average depth of 200 yards, some being as much as 500 yards. The derricks are 30 to 60 feet high. As motive power for boring and pumping from the wells, steam is usually employed. In 1898 a company was formed to erect a central electric station of 1,500 horse-

power in order to use electro-motors instead of steam-engines. Each of the derricks is furnished with a motor which is used for boring and subsequently for winding up the oil. It sometimes happens that when oil is struck, the petroleum, after demolishing the derrick, spouts up as a fountain (Fig. 2). A difficulty in the way of installing alternating current motors, is the risk of fire, for, unfortunately, conflagrations are frequent and extensive. In the spring of 1902, for example, more than 100 derricks were burned. Disastrous fires, due to incendiarism, have

FIG. 2.



PETROLEUM FOUNTAIN AT BAKU.

also occurred quite recently. The electro-motors are consequently placed on a solid masonry foundation, and in a separate brick building (Fig. 3.) The motor is thus kept away from the derrick, which is specially in danger of fire.* The production of oil is largely in the hands of Nobel Brothers, and of the Rothschilds. Of late years, however, a large amount of British capital has been invested in these undertakings, the chief companies being the Russian Petroleum and Liquid Fuel Company, Ltd. (capital £1,200,000); the Baku Russian Petroleum Company, Ltd. (capital £1,500,000); the Schibaieff Petroleum Company, Ltd.

* According to Mr. L. Gaster, experience in the Roumanian oilfields tends to show that the polyphase motor is the best for boring and pumping, and, if properly enclosed, can be brought quite near to the well without danger.

(capital £1,150,000); the European Petroleum Company, Ltd. (capital £1,100,000); and the Spies Petroleum Company, Ltd. (capital £700,000). British capital is also being invested in the Chatma oil field, a promising field almost midway between Batoum and Baku.

Although no petroleum is raised in Great Britain, oil shale is in Scotland the basis of a considerable industry. The county of Linlithgow yields more than half the production. The mineral occurs in beds in sandstone at the base of the carboniferous strata. Similar deposits are mined at Autun and Buxières-la-Grue in France, and in New South Wales. In 1901 the production of oil shale in Scotland

FIG. 3.



ELECTROMOTOR HOUSE AT BAKU OIL-WELLS.

was 2,354,356 tons, and of kerosene shale in New South Wales 54,774 tons. The oil shale mines of Scotland yield a product of greater money value than the tin mines of Cornwall.

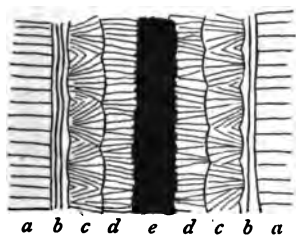
Ozokerite.—In 1883 this mineral-wax formed the subject of a course of Cantor lectures by Mr. L. Field,* who described the properties of the mineral and its use in the manufacture of candles. The most important deposit of ozokerite mined is at Boryslaw, in Galicia. As long ago as 1856 petroleum was obtained in this district from shallow wells. The mineral-wax was known, but it was not until 1862 that it was raised and purified. It fills fissures in Miocene shale and sandstones forming a kind of network. Serious gas explosions are not uncommon. The output of ozokerite in Galicia in 1901 was 2,707 tons. Mining

* *Journal of the Society of Arts*, vol. 31, pp. 821, 833, 46, 857, 869, 881.

there was conducted in an extremely primitive manner until September 16, 1897, when a law was passed which required the shafts to be at least 60 yards apart and provided with adequate machinery for ventilation. The industry has, in fact, been placed on so satisfactory a basis that a great future is in store for it. The present selling price of ozokerite is 9d. per lb., or £84 per ton.

Asphalt.—The term asphalt is usually applied to limestone impregnated with pure bitumen. The latter is sometimes met with in veins, as at Bentheim, in the province of Hanover, where veins (Fig. 4) three feet wide occur in shale of cretaceous age, the veins containing black asphaltum, clayey asphalt, radiated iron pyrites, and calc-spar. In New

FIG. 4.



ASPHALT VEIN, BENTHEIM.
(Heinrich Credner.)

a, Gault shale; b, clayey asphalt; c, radiated iron pyrites; d, calc-spar; e, pure asphalt.

Brunswick veins of asphalt, known as albertite, occur in bituminous schists and are mined on a large scale. Very pure asphalt is also obtained from the Dead Sea. This material, which is not worked at present, was doubtless used in ancient times as water-tight cement in buildings. It was used by the ancient Egyptians for embalming their dead, and it is remarkable that there is no record of its use throughout the middle ages, up to the 18th century. A celebrated deposit that has been worked for a century, is the Pitch Lake of Trinidad. The lake is a mile and a-half inland from Brea. It is very irregular in shape, and about a mile in length. It is of unknown depth, and solid enough to be walked over. The pitch is hacked out by picks. Wherever it is abandoned for a few days, the cavity fills up from below. In one part of the lake the pitch is hot and plastic, and this soft spot is continually changing. Plant for dealing with the pitch on a large scale has been erected by the New Trinidad Lake Asphalt Company. Mr. J. W. Gordon and Professor Henry Louis

consider that at the present rate of extraction of about 120,000 tons per annum from the Pitch Lake, the deposit should still last for more than a century. In Barbados, manjak (mineral pitch) occurs in veins in infusorial earth.

The mining of asphalt rock has rapidly developed since the first asphalt pavement was laid down in Paris in 1838. The oldest mines are those of Seyssel, near Bellegarde on the Rhone, and of the Val de Travers in the Swiss Canton of Neuenberg. The asphalt rock of the Val de Travers is a bituminous limestone of cretaceous age. The bed is 12 to 24 feet in thickness, and contains 10 per cent. of bitumen. At the present time the mines of Ragusa, in the island of Sicily, are the most important, the production having increased from 4,000 tons in 1879, to 79,000 tons in 1901. The asphalt occurs in Miocene limestone, and contains 10 to 18 per cent. of bitumen. The product is very similar to those of Seyssel and Val de Travers, so that it can be mixed with them without lessening the binding properties. The output of the other mines in Europe (Seyssel, Val de Travers, Chieti in the Abruzzi, Limmer and Vorwohle in Hanover, Lobsann in Alsace, Auvergne, and Syzrane in Russia), may be estimated at 120,000 tons annually. In the United States asphalt is mined chiefly in Utah and California. The world's production is about 600,000 tons annually, the principal producing countries having raised in 1901 the following amounts:—

	Metric tons.
France.....	285,000
Trinidad	129,797
Italy.....	104,111
Germany.....	90,193
United States	57,290
Spain	3,956
Barbados	1,044

Particulars of the production of Switzerland are not available. Small quantities are also produced in Russia, Mexico, Turkey in Asia, Colombia, Canada, and Holland. The average price of crude asphalt at Ragusa is 13s. per ton. Several English companies are engaged in asphalt mining. The Val de Travers Asphalt Paving Company, Ltd. (capital £100,000), registered in 1871, made in 1902 a trading profit of £42,256. The Limmer Asphalt Paving Company, Ltd. (capital £40,000), also registered in 1871, paid in 1901 a dividend of 10 per cent. and a bonus of 10 per cent. The Neuchâtel Asphalt Company, Ltd. (capital £569,880), paid in 1901 a dividend of 14s.

per £10 share. The United Limmer and Vorwöhle Rock Asphalt Company, Ltd. (capital £60,000), paid for each of the 12 years up to 1901 a dividend of 10 per cent. and a bonus of $2\frac{1}{2}$ per cent.

Within the last few years asphalt deposits of considerable extent have been opened up in the Indian territory, United States. At Tar Springs the deposit occurs in a basin about a mile in diameter, the asphalt being met with in sand and sandstone which it has thoroughly impregnated. The overburden is removed and a thin capping of barren sandstone blasted off. The bed is then loosened by ploughs drawn by teams of four or six mules and excavated by wheeled scrapers. The sands contain 10 to 14 per cent. of asphalt, and three to six per cent. of heavy oil. The asphalt sands are tipped and shovelled to a feed bin, and conveyed thence to a disintegrator, which is heated by steam to facilitate the passage of

the adhesive asphaltic material. The broken-up material is raised by an elevator to the concentrating apparatus in the upper part of the building. The concentration is based on the fact that the associated heavy oil adheres to the asphalt and buoys it up, while the sands, freed from both asphalt and oil, and washed by warm water, are discharged by an under-conveyor. The asphalt and oil rise to the surface of the water, and are discharged by the upper conveyor. This method of separation was devised by Mr. R. V. La Grand, and is similar to the Elmore oil process of concentrating ores. The elimination of water and oil from the asphalt is effected by evaporation. The total loss in concentrating and refining, varies from four to six per cent. The refinery cost £8,000. The cost of mining is 4d. per cubic yard, and that of refining, about £2 per ton. The plant is designed for a capacity of 25 tons finished product per day of 24 hours.

LECTURE II.—DELIVERED NOVEMBER 30, 1903.

Salts.—Rock salt—Potash salts—Borates—Alums—Nitrates—Phosphates.

From a mining point of view all minerals occurring in nature that are soluble in water may conveniently be classed as Salts. About twenty such minerals are of economic importance, and in some cases are mined in enormous quantities.

Salt.—Salt is one of the most widely distributed of minerals. It is a constituent of sea water. Salt lakes exist in numerous localities,

and it occurs in beds in most of the geological formations. Important papers were read before the Society in 1894 by Mr. Thomas Ward,* describing the manufacture of salt in different parts of the world, and in 1889 by Mr. P. L. Simmons,† giving statistics of its production and consumption. Since the date of Mr. Simmons's paper the world's production has

* *Journal of the Society of Arts*, vol. 43, p. 77.

† *Ibid.*, vol. 37, p. 249.

almost doubled. In 1901 the world's production of rock salt, evaporated salt, and sea salt, according to returns collected by Sir C. Le Neve Foster, was as follows :—

	Metric tons.	Per cent. of total.
United States	2,612,824	20.1
Russia	1,968,005	15.1
United Kingdom	1,811,670	14.9
Germany	1,563,800	12.1
India	1,120,239	8.7
France	910,350	7.0
Japan	659,118	5.1
Austria Hungary ...	517,220	4.0
Italy	435,187	3.3
Turkey	203,128	1.5
Venezuela	155,800	1.2
Other countries	907,248	7.0
World's total	12,864,589	100.0

The annual consumption of salt as a condiment is estimated by Mr. F. A. Fürer to be as follows per head of population in the principal countries of the world :—

	lbs.
France	11.4
Italy	13.7
Germany	16.0
Austria	17.0
Russia	18.6
United Kingdom.....	27.5
United States	33.0

In Germany, careful statistics are kept of the consumption of salt for agricultural and industrial purposes. It amounted in 1901 to 565,517 tons, or 22 lbs. per head of population. Under this category there were used in soda and Glauber salt manufacture, 254,433 tons; in chemical works, 102,553 tons; in the metal trades, 21,899 tons; for cattle food, 109,949 tons, and for manure, 3,441 tons.

There is no country better supplied than England with beds of salt and brine springs. The most important beds are those in Cheshire, where mining has been carried on since the year 1670. At the mouth of the Tees, where salt was discovered in 1862, the beds cover 20 square miles, and each square mile contains 100,000,000 tons of salt. Salt is also extracted at Carrickfergus, in Antrim. Salt is mostly obtained from brine, the quantities of rock salt mined being less than one-tenth of the total output. At Northwich in Cheshire, there are two beds of rock salt of Triassic age, each 84 to 90 feet thick, and separated by 30 feet of marl.

The output of rock salt from mines in 1902, comprised 68,224 tons from Lancashire, 61,440 tons from Cheshire, and 32,529 tons from Antrim. Figures given by Fürer, show that in Cheshire, Durham, Staffordshire, and Worcestershire, there are 55 salt works with 1,316 salt-pans. In 1888, numerous salt works were consolidated by the Salt Union, Ltd. (present capital, £1,400,000). From the bed of rock salt, about 100 feet thick, near Middlesbrough, large quantities are pumped up in the form of brine from deep boreholes. The brine is delivered into a large pond whence it flows into iron evaporating pans, 70 feet long, 24 feet wide and 16 to 20 inches deep, heated by the flame of a coal fire. As table salt, the salt obtained from brine is universally preferred to rock salt. The process employed for manufacturing salt from brine is extremely simple. It consists merely in the evaporation of the water and the collection of the salt that is deposited. Although in England the manufacture of salt has been carried on since the Roman occupation, the process has undergone so little change that the plant in use is not essentially different from that employed 1,400 years ago. Attempts have, however, been made with success to economise fuel. Sir Lowthian Bell, for example, utilises the heat of blast-furnace slag. At the works of Bell Brothers, Ltd., there are also five salt-pans heated by blast-furnace gas. The gas is first used for heating steam boilers and the waste heat is then used for salt evaporation. Owing to their depth below the surface many beds are not mined but are pumped up as brine. At Syracuse, New York, wells are sunk not into the salt bed itself, but into an ancient gravel deposit saturated with brine. The brine is run in a continuous stream into large pans 130 feet in length, and as it evaporates, the salt is deposited on the bottom, and is scraped on to the sloping sides of the pan. In Austria, salt mines were worked in Tyrol in 1280, and even in these operations old workings were found. The salt-clay had almost completely re-filled the old excavations. Modern mining operations have again encountered these old workings, and the objects found render it evident that salt mining was here carried on by the Celts 900 B.C. Few metallic objects have been discovered. On the other hand, numerous wooden articles and remains of skin clothing have been found in good preservation. The prehistoric salt mines at Hallstatt reached depths of as much as 200 yards. The archæo-

logical remains consist of beechwood that served as handles for copper and bronze axes, a double pick of beechwood, wedges of black serpentine and crowbars of copper and bronze. For supporting the workings larchwood was used. Torches made of pine shavings, and two fur caps and a piece of coarse woollen fabric were also found. Specially noteworthy are two sacks for the transport of salt, preserved in the Vienna Museum. They are 30 inches high and made of raw ox-hide. For carrying the sacks there is a leather strap that passed over one shoulder, and a wooden handle 15 inches long fastened by two straps to the upper part of the sack. With this handle the sack could be held securely when full, and on releasing the handle the contents of the sack could be tipped backwards. A loop was provided for hanging up the sack.

The world-famed salt mines at Wieliczka, near Cracow, have been worked since pre-historic times. The first mention of Wieliczka occurs in a charter granted by King Casimir I. in 1044, but the discovery of the deposits dates back to pre-historic times, although the legend is that Wieliczka has to thank St. Kunigunde for its riches in salt. When Boleslaus the Shameless was betrothed to Kunigunde, daughter of the Hungarian King Bela IV., she expressed the wish to see her land, which suffered from an absolute lack of salt, blessed in its possession. She prayed fervently, and her prayer at last was granted. The wedding ring of this princess which she had cast into a well in Hungary when on a visit to her father, was miraculously found again, during her stay in Wieliczka, in a block of salt. Since 1260 mining has continued with little interruption. In 1638 the mine-surveyor, Martin German, a Swede by birth, made the first plan of the Wieliczka mines. In 1772 the mines passed into the possession of the Austrian Government. A great change in the methods of mining was then made. The lavish gifts of salt to Polish individuals and monasteries were cut down, and systematic mining operations were introduced.

The rock-salt bed is of lower Miocene age. In sinking the shafts, after various beds of clays, sands, marls, and gypsum, unstratified green rock salt was encountered, containing salt masses, and detrital sandstone, limestone and granite in greenish gray clays, and lastly the stratified salt-measures, consisting of beds of salt, clay, and anhydrite. The thickness of the stratified salt-measures opened up amounts to 150 yards. The worked out un-

stratified green-salt masses form the portion of the mine that have long aroused the amazement of tourists. From the earliest times the mine has been worked by shafts, eight of which are still in use, the deepest, the Kaiser Josef shaft, having a depth of 985 feet. At this shaft in 1860 the first steam-winding engine at these mines was started. During the past century the space excavated for the extraction of salt amounts to 3,000,000 cubic yards, and the length of roadways driven to 115,000 yards.

Ample opportunity is given to enable visitors to see these remarkable mines. The chief

FIG. 5.



ST. ANTHONY'S CHAPEL, WIELICZKA SALT MINES.

object of interest shown is the St. Anthony's Chapel (Fig. 5), 25 feet long, 20 feet wide, and 10½ feet high, hewn, complete with altar, statues, and pillars, in the year 1698 out of the solid green rock salt. In the Kaiser Franz chamber there are two pyramids hewn in salt to commemorate the visit of the Emperor in 1817. In the Walczyn Steinhauser chamber, which was excavated in 1743, the ancient method of lowering the miners in slings used to be shown. The visitors ferry across the underground lake of the Crown Prince Rudolf grotto. Lastly the ball-room of the Letow chamber is visited. Other objects of interest are the imposing Michalovice chamber, made

in 1717-1761, which measures 120 feet in height, 60 feet in width, and 90 feet in length, and is illuminated by a chandelier of 200 candles; and the Count Goluchowski railway station, a chamber 170 feet long, 65 feet wide, and 52 feet high, near the main shaft. Owing to the necessity for supporting the workings, these ancient excavations will all in time have to be filled in, and future visitors to this ancient mining town will hardly realise its ancient glories.

The Alpine salt mines of Aussee, Hallstatt, and Ischl in the Austrian Salzkammergut, of Hallen in Salzburg, Hall in Tyrol, and Berchtesgaden in Upper Bavaria, are situated amidst the magnificent mountain scenery so familiar to tourists. The deposits are very similar and in each case the salt is obtained from the impure material by an artificial washing out. The Berchtesgaden mines, which are visited

FIG. 6.



ILLUMINATED GROTTTO, BERCHTESGADEN SALT MINES.

by 20,000 tourists annually, date back to the twelfth century, and their history can be followed from the commemoration marble tablets put up in the mines from 1514 to the present time. One of these, dated 1726, can be seen in the illuminated grotto (Fig. 6) of transparent rock salt, which is the greatest attraction for visitors.

It is a curious fact that from time to time fire-damp explosions take place in salt mines. Indeed, the first fire-damp explosion recorded occurred at a salt mine at Hallstadt, in Austria, on September 9th, 1664, twenty years before what is generally supposed to be the first historical evidence of the presence of fire-damp, given by Robert Plot in his "Natural History of Staffordshire." In several localities, notably at Stassfurt and at Wieliczka, the salt contains bubbles filled with the various compressed gases which, when the salt is dissolved,

give rise to a crackling noise. Liquid inclusions in rock salt are extremely frequent. Some are visible to the naked eye, others are microscopic. The enclosed material is usually a hydrocarbon. Combustible gas was evolved in large quantities from a fissure in the marl in the rock salt at the Szlatina mine, Hungary, and was used for lighting the workings. A serious explosion occurred here on August 28th, 1896. Similar emanations of gas were utilised at Zugo, in Transylvania, and at the Bex salt mines in the Canton of Vaud, Switzerland. Fire-damp has been used for lighting the workings, being received from the fissures in cast-iron pipes. Such occurrences are fairly frequent in the Wieliczka mines. An outburst of gas in 1828 burned for some weeks with a flame 1½ feet in diameter, and the ancient records make frequent mention of these outbursts. The earliest record occurs in a poem written by Adam Schröter in 1564, entitled "Salinarum Vielicensium descriptio." There is also preserved at the mines an old plan made in 1638 to 1648, on which fiery workings are duly marked. It is only recently that the firing of the gas has been prohibited. At the present time stress is laid upon good ventilation and suitable illumination. Hand-driven fans are employed, and the air current is conveyed through 4½-inch zinc pipes. Canvas pipes have recently been successfully introduced. Open lamps with vegetable oil are used, electric lamps being kept in reserve in case of explosions. Mueseler safety lamps have also recently been adopted in fiery working places. The miners, who are extremely conservative, object to safety lamps, as they are much heavier than ordinary oil lamps. Advance bore-holes are now driven to detect the occurrence of gas accumulations. With the Elliot rock drill three men can easily bore a hole 50 yards in depth, safety lamps being used during the operation for lighting.

The rock salt deposits of Hungary, to which I have referred on a previous occasion,* are second to none in Europe, and are apparently inexhaustible, the most important being in the Marmaros and in Transylvania. To the former belong the Szlatina salt mines, where the quantity of salt available is estimated at 18,000,000 tons, and to the latter, the Deésakna mines, where the quantity available is 800,000,000 tons. Besides these there are salt beds in many other parts of Hungary.

* *Journal of the Society of Arts*, vol. 36, p. 266.

For drying and packing the salt many ingenious inventions have been proposed. A fertile inventor in this field was the late Carl von Balzberg. The packing of salt in the tropics is a subject of such importance that the Government of the Dutch Indies was induced to offer a valuable prize for the best suggestion. Mr. von Balzberg, who was director of the Ischl Salt Works, was induced to compete by the fact that he was at the time engaged on a thorough investigation of the subject of compressing salt into briquettes for the Austrian works, and he concluded that this procedure might be recommended as the best method of packing. For this suggestion he received the prize. He employed a hydraulic press working up to a pressure of 200 atmospheres. By this pressure the salt is reduced to half the volume of the loose salt, so that great advantages in shipping and storing are presented. The Ischl Salt Mines are increasing their briquette plant, and the Aussee Salt Mines are installing plant to turn out in 24 hours 40,000 to 45,000 salt briquettes weighing 2 lbs. each, and containing not more than 1 per cent. of moisture.

It is not European salt that supplies the Soudan, the Niger district, Lake Tschad, and the Belgian Congo, but salt in blocks derived from Sahara. It is transported in the state of blocks weighing about 50 lbs. All travellers are familiar with these blocks of salt, which form one of the principal objects of Soudan commerce. This crude salt, impure and coloured by foreign matter, presents the advantage that it is solid, convenient to handle, and weather resisting. From the place of production to their destination these blocks of salt have to travel enormous distances, as much as 1,200 miles. The expenses of so long a journey, aggravated by the perils to which caravans are subjected, explains the increase in price as the distance from the starting point becomes greater. Salt which costs 6d. per lb. at Timbuctoo, fetches 1s. on the Upper Niger, and 2s. at Kong. A Marseilles company is putting on the market very pure salt in the form of compact blocks presenting the appearance and polish of white marble. The blocks have the same dimensions as the natural product of the Sahara. The latter is obtained from three principal points: the Idgil deposit that supplies Western Africa, the Taodenite deposit that supplies Sahal, the Niger and the Congo; and the Bilma deposit that supplies East Africa and Lake Tschad. These deposits have been formed by the evaporation of inland salt lakes.

The origin of such inland salt lakes is a subject of constant controversy. This has, for example, been the case with the salt lake of Larnac in Cyprus, a deposit of considerable economic importance. As the lake is separated from the sea by a barrier, older writers considered that the salt was not derived from the sea, but from the soil. Careful levelling and boreholes have proved that the salt was not derived from a rock salt bed, but permeated from the sea through a porous conglomerate. When a stream containing salts in solution flows into a lake with no outlet, such as the Great Salt Lake in Utah, or the Dead Sea, the water is evaporated while the impurities remain. At the Great Salt Lake, the Inland Salt Company's workings are situated near Garfield Beech. The water is pumped from the lake into a series of ponds which cover over a thousand acres. Pumping ceases in August, and a layer of salt seven inches deep is found to be deposited from 49 inches of lake water. The yield of salt is at the rate of 150 tons per inch depth per acre.

In Southern Europe and in tropical countries, the heat of the sun is utilised to evaporate salt water in shallow pools. The extraction of salt by evaporation from sea water, can best be seen in the Trapani district of Sicily, where the industry dates back to 1507. Forty-five salt works now occupy nearly the whole shore up to the gates of Marsala. Though the process of obtaining the salt is very primitive, the yield is abundant on account of the purity of the sea-water and the settled weather in summer. The average production is about 200,000 tons a year. Practically the whole area of a salt works is occupied by evaporating pans. The preparation of the water is constantly cared for throughout the year. It is passed through a succession of pans, evaporating as it goes until it contains 30 to 35 per cent. of salt, when it is ready for final evaporation at the proper season, until which it is kept stored. The pans are about 90 feet square and 15 inches deep, with a hard bottom of sand. The water is brought from the sea to the pans by windmills. Dry, clear weather and a light breeze give the best conditions for making salt. When the pan are dried up, the salt is collected in small heaps and left to dry for 24 hours. Then it is removed from the pan and piled up in a rectangular heap, which is covered with tiles to keep off rain and dust. Each of these heaps contains about 300 tons of salt, and they are all close to channels where lighters moor to load the salt and then

convey it to the ships. A pan will yield salt three, or even five times in a season, which closes with the coming of rain and damp nights in the autumn. The salt is of three qualities, fine, coarse, and ground marine salt, the last being only used locally and never exported. The salt is exported to Scandinavia, Canada, and the United States, and to all places where there is a large industry in salt fish. A similar method of extraction by solar evaporation is employed near Karachi in India.

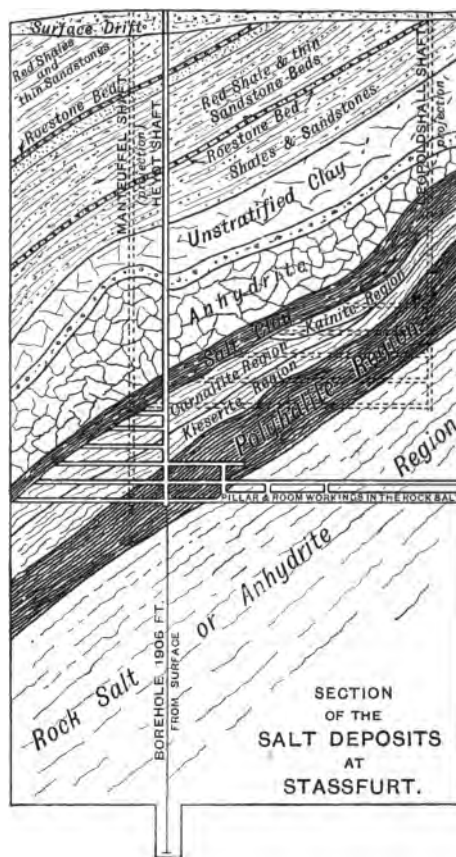
The search for deep-seated salt beds is constantly being prosecuted. In Germany numerous boreholes have recently been put down for salt. Some of these have been carried out with great expedition. At Kaiseroda, for example, a borehole begun on January 2nd, 1894, struck salt at a depth of 525 feet, on January 15th. The greatest depth attained in boring for salt was 4,650 feet, at Salzdetfurt, in Hanover. In Western China boring for brine is actively carried on. The boreholes are 2,200 to 3,300 feet deep, and are sunk by percussion with all the machinery made of bamboo.

Potash Salts.—With rock salt, in certain cases, a number of other salts occur to which brief reference may be made. Among these the natural potash salts are the most important. The rich stores of these salts, of which North Germany possesses the monopoly, were first utilised in 1861, when mining operations were begun at Stassfurt. The production and consumption increased so rapidly, that in 1901 the production of kainite and other potassium salts amounted to 3,534,895 tons. The salts are used for manufacturing purposes and as manures for crops and garden produce. The deposits are of Triassic age, and cover a vast area, the beds being usually at a considerable depth below the surface. Both the production and prices are regulated by a syndicate. The working of a commercial trust is well illustrated by the operations of this Potash Syndicate, one object of which is to supply German consumers with a cheap article, while much higher prices are charged to foreigners.

The salt industry of Stassfurt is a very old one, dating back to legendary times. The oldest existing title is dated 1461. The development of the salt mines owed much to Anna von Schladen, who was abbess of the convent at Hecklingen, and contributed funds in 1452 for the sinking of an important brine well which was, for a long time, the chief source of supply. A portrait of the abbess is still preserved at the mines. In 1797 the

wells were purchased by the Prussian Government who, in 1839, began boring with a view to discover the bed from which the brine was obtained. In 1851 the boring, which had reached a depth of 1,906 feet, was given up, salt having been struck at a depth of 850 feet. In 1852 the first two shafts were begun, and in 1857 salt was first mined at a depth of 1,100 feet. In 1860 the potash salts, which had hitherto been thrown aside as

FIG. 7.



SECTION OF THE SALT DEPOSITS AT STASSFURT.

impure salt, were exploited. A section of the strata passed through by the two shafts is shown in Fig. 7. The bottom of the bed of rock salt was not reached. The beds above consist, in ascending order, of polyhalite (sulphate of potassium, magnesium and lime), kieserite (sulphate of magnesium), carnallite (chloride of potassium and magnesium), and kainite (a secondary formation caused by action of water on kieserite and carnallite). The upper bed of rock salt, resting on anhy-

drite, is also of secondary formation. Altogether some 16 different minerals occur in the Stassfurt deposits, but only the carnallite, kainite, kieserite, and salt are of commercial value. In May, 1900, the Achenbach shaft, 1,280 feet deep, was flooded, and it became necessary to supply the chemical works at this shaft with crude potash salts from other mines. A railway at the surface to transport the material was not practicable, and the number of public roads to be crossed rendered a wire ropeway too costly. An underground railway was therefore constructed, on which electric locomotives are used. Altogether the mechanical equipment of the Stassfurt mines is of the highest order. Siemens and Halske's electric drills are used for boring in the salt. Potash salts have also been raised since 1887,

FIG. 8.



BORAX MINE, NEAR DAGGETT, CALIFORNIA.

at the Hercynia mine at Vienenburg, in Brunswick.

Borates.—With the potash salts at Stassfurt boracite (borate of magnesium), occurs. A second boric acid compound, natural borax (borate of sodium), occurs in vast quantities in the so-called borax lakes of California and Thibet. Borax occurs in the Death Valley region in a regular stratum interbedded with semi-indurated sands and clays. The mines at Borate are the chief producers of borax and boracic acid in the United States. At this place, 12 miles north of Daggett, in the old Calico mining district, calcium borate occurs as a bedded deposit (Fig. 8) 5 to 30 feet in thickness, interstratified in sedimentary strata. There are two outcrops, either on parallel beds or on one bed that has been closely folded. The world's production of borates in 1901 was as follows:—

	Metric tons.
United States (calcium borate)	21,080
Chili (calcium borate)	11,455
Turkey (calcium borate)	9,000
Peru (calcium borate)	7,080
Bolivia (calcium borate)	3,065
Italy (boric acid)	2,558
Germany (pure boracite)	164

The uses of borax have been fully dealt with in a paper by Mr. E. L. Fleming.* In 1899 various borate mines were consolidated under the name of Borax Consolidated, Limited (capital £1,400,000).

Alums.—Alum was formerly made from natural salts, but at the present time cryolite and bauxite have taken their place. Pickeringite (magnesium alum) is found in the greatest abundance in the rainless district of Tarapaca, Chili. Alum-stone or alunite (hydrated sulphate of aluminium and potassium) occurs in fissures in felspathic rocks at the Tolfa near Civita Vecchia, and in New South Wales and many localities. Most of the alum made in England was formerly obtained from alum shale and similar substances which occur at Whitby in Yorkshire, at Campsie in Scotland, in Bohemia, and elsewhere. The production of alum shale in England in 1902 was 5,664 tons, valued at £708. The Italian production of alunite in 1901 amounted to 4,900 tons, and that of Australia to 3,146 tons.

Brief mention may here be made of the natural sodium carbonates; natural soda and trona found in dry lakes in Arizona, Egypt, and other arid regions. In the same way the natural sodium sulphates, Glauber salt and thenardite are met with. The most extensive deposits are at Tiflis and Baku, the Russian production being about 5,000 tons annually.

The double chloride of aluminium and sodium, known as cryolite, presents the remarkable peculiarity of occurring in large masses in Greenland without having been met with elsewhere. It has been mined opencast since 1857, and utilised for the manufacture of aluminium and alum. It occurs in a vein 150 feet wide, in granite. The quantity obtained from Ivigtut in 1901 was 7,997 tons.

Nitrates.—Since the year 1850 an important industry has developed in the preparation of mineral fertilisers. The raw materials for this industry are the potash salts to which reference has been made, Chili nitrate, guano, and natural phosphates. The phosphoric acid contained in many iron ores is also utilised in the form of basic slag obtained by the basic

* *Journal of the Society of Arts*, vol. 39, p. 523.

process of steel making. Nitrate of potassium is formed whenever animal or vegetable remains come in contact with rocks that weather easily. In India, in 1901, the production was 11,524 tons. In 1821, on the arid west coast of South America great deposits of nitrate of sodium were discovered. They occur chiefly on the Rio Loa, near Caracoles and Taltal. The raw material, known as *caliche*, is converted into pure nitrate by leaching with water and a subsequent process of crystallisation. The crude nitrate is found in beds 6 inches to 12 feet in thickness under a covering of conglomerate. In 1901 the world's consumption of Chilean nitrate amounted to 1,375,400 tons, of which 1,162,400 tons were used in Europe. In 1901 exports of nitre from Chili reached the record value of 581,879,965 dollars. Of the total, 34·10 per cent. went to Great Britain, 29·59 per cent. in Germany, 14·52 per cent. to the United States, and 9·30 per cent. to France. A large amount of British capital is invested in the nitrate fields. A combination of nitrate producers came into force in 1901, and is intended to cover a period of five years. The effect was to cause an advance of 40 per cent. in the price. The lowest price in London was in 1898, when the average was 7s. 4½d. In 1902 the average was 9s. per quintal. The following is a list of the chief nitrate companies before the public, together with the amounts of their capital:—

	Total Capital. £
Alianza	1,000,000
Amelia.....	391,000
Anglo-Chilian.....	1,034,900
Lagunas Nitrate	900,000
Lagunas Syndicate	1,160,000
Lautaro	598,000
Liverpool.....	110,000
London	160,000
New Tamarugal.....	545,130
Rosario	998,500
Salar del Carmen	153,500
San Jorge	300,000
San Pablo	160,000
San Sebastian.....	143,750
Santa Rita	113,800
Santiago	269,600

Phosphates.—As raw material for the manufacture of super-phosphate, the natural phosphate of lime is used. It is met with in two varieties, crystallised as apatite or in the form of a rock as phosphorite. The former occurs in large quantities in the south of Norway and in the Spanish provinces of Estremadura, whilst phosphorite occurs in Florida. In Great

Britain, foreign competition has interfered with the phosphate industry. The mineral is obtained from beds in the cretaceous rocks in Bedfordshire and Cambridgeshire. In 1901 the world's production of phosphates comprised:—

	Metric tons.
United States	1,507,958
France	535,676
Algeria.....	265,000
Belgium	215,000
Tunis	172,375
Christmas Island	37,000
Russia	25,663
Aruba (Dutch West Indies)....	10,413
Spain	4,220
Canada	937
Norway	300
United Kingdom	80

The well-known deposits at Redonda in the Leeward Islands (aluminium phosphate), were not worked in 1901.

The growing importance of the phosphate industry of Northern Africa is remarkable. At Gafsa, where most of the Tunisian phosphate is obtained, the mineral was not discovered until 1885. Since the concession for working it was granted in 1896, the French have constructed a railway 28½ miles long from the oasis of Gafsa to the mines, as well as one 15½ miles from the port of Sfax to the mine, and it is expected that the output for 1903 will be 300,000 tons. The phosphate beds occur in rocks of lower Eocene age. The principal bed now being worked is 13 feet thick, and contains 59 to 61 per cent. of tribasic phosphate of lime, and is, therefore, extremely rich. This phosphate placed on the trucks at the mines does not cost more than 4s. a ton. The production of phosphate in Tunis continues to increase. In 1899 the output was 63,209 tons, whilst in 1902 it was 263,493 tons.

Of the American phosphate deposits, those of Canada, South Carolina, and Florida are of chief importance. The existence of nodular amorphous phosphate deposits in Florida was known many years ago, but they remained unworked until 1888. There are four classes of phosphates, the hard rock, the soft rock, the land pebble and the river pebble, and the work of exploration has now extended all over Florida in each of the varieties of deposits. In several of the mines the deposits are of very great size. At Anthony, for example, there is a remarkable deposit of drift phosphate, one cubic yard yielding 500 lbs. of washed material averaging 76 per cent. of phosphate of lime. The boulder material is worked by

quarrying after the top soil has been removed. The thickness of the boulder deposits is very variable. In one case it was 50 feet. Sometimes the difficulties of dealing with the overburden of soil are obviated by the use of a chain conveyor. At some of the larger mines complicated dressing plant is employed for washing, screening, and drying the mineral. In mining the hard rock or high grade boulder deposits, care has to be taken to select the different qualities of mineral. This is the case notably in extracting boulder material from clay and sand in Citrus country. Unlike the boulder deposits, the pebble or drift deposits are marked by great regularity. The chief centre for pebble phosphates in Florida is Peace River. The deposits are worked by a centrifugal steam suction pump placed on a barge. The mixture of sand and phosphate drawn up is brought into revolving screens, whence the sand is washed back into the river. The cleaned pebbles are discharged at the rate of 12 tons per hour, and are conveyed in boats to the dressing floor, where they are taken up by an elevator to a drying room, dried by hot air, screened once more, and are then ready for market. The total cost of raising, dressing and loading varies from 2s. to 8s. per ton. Geologically the rock phosphates appear to be the deeply eroded remnant of the phosphatised surface of the Middle Tertiary limestone, the conglomerate deposits are of Miocene age, whilst the river drift deposits are of more recent age than the Pleistocene sands that cover the entire peninsula. In South Carolina the celebrated phosphate beds are of great extent. The total cost of production of land phosphate is 14s. per ton. The mineral occurs in nodules in a bed 8 inches thick, and is thought to be of post-Pliocene age. In Canada the phosphate occurs in rocks of Laurentian age in Quebec and in Ontario. The Canadian apatites cannot be mined and shipped at a profit unless they contain 75 to 90 per cent. of the pure mineral. The method of working is in many cases very primitive. In some of the larger mines, however, proper development work has been undertaken with a view to lasting profits rather than immediate gains. In Sweden and Norway veins of apatite associated with iron ore are met with, the deposits containing as much as 60 per cent. of apatite. I have described in a paper read before the Society in 1897* the utilisation of

this apatite at Lulea, in the preparation of Wiborgh phosphate, a highly valuable fertiliser of great solubility. In Picardy phosphates of lime occur in the form of phosphatised chalk and of phosphatic sand. The phosphatised chalk occurs in ellipsoidal basins varying in diameter from 300 to 10,000 feet, and at the same time the deposits are lenticular. At the base a conglomerate of chalk nodules rich in phosphate usually occurs. The genesis of the phosphatic chalk is explained by Mr. J. Gosselet in the following manner:—A pause in the sedimentation of the white chalk was followed by a penetration of its surface by a phosphate of lime solution, which hardened it and altered it into a richly phosphatised chalk. The hardened surface emerged, and a crust of phosphate was deposited on it, a breccia being formed at the expense of the hard bed. The encrusting process continued, and the crust was perforated by large boring organisms. Much of the hard rock was destroyed and re-deposited. A deposition of normal phosphatic chalk followed. The phosphatic sand was no doubt formed by the chemical action of rain water, charged with carbonic acid, on the phosphatic chalk. It is made up almost entirely of small grains of phosphate of lime, and forms a layer on the walls of pockets in the phosphatic chalk. The pockets vary in depth up to 33 feet. These pockets at Beauval, Somme, present a striking appearance, as also do the workings of phosphatic chalk at Hardivilliers, Breteuil, Oise, and of phosphatic sand at Harquicourt, Aisne.

The origin of phosphates has been much debated. The general opinion is that there are three classes of mineral phosphates, the first being the apatite found in the older crystalline rocks, which are regarded as of primordial origin; the second are represented by the phosphorites of Estremadura, which are essentially deposits from mineral waters; whilst the third or concretionary phosphates are of animal origin, as is shown by the presence of organic remains and of nitrogenous organic matter and nitrates. Mr. J. J. H. Teall, who has devoted much attention to the natural history of phosphatic deposits, is of opinion that calcium phosphate may be formed by the accumulation of animal remains by the replacement of carbonic acid by phosphoric acid through the action of solution arising from the leaching of guano, or the decomposition of animal matter, by direct deposition from solutions of calcium phosphate, and by chemical precipitation due to the interaction of solutions

* *Journal of the Society of Arts*, vol. 46, p. 69.

containing ammonium phosphate and calcium bicarbonate.

These few remarks will, I trust, give some idea of the character of the phosphates worked. The importance of a knowledge of the world's phosphate resources is manifest when we learn

that the quantity of phosphoric acid annually removed from the soil of the United States alone by the cultivation of cereals amounts to 2,714,584,473 lbs., or 19 lbs. per acre. A similar estimate for the hay crop is 12½ lbs.

LECTURE III.—DELIVERED DECEMBER 7, 1903.

Stones : — Flint—Sandstone—Limestone—Marble—
Dolomite and Magnesite—Slate—Eruptive rocks
— Mica — Felspar — Clays — Gypsum—Sulphur—
Asbestos—Bauxite—Other earthy minerals.

STONES.

In all countries stone used as building material has long formed a most valuable mineral product. Even in prehistoric times monuments were decorated with columns and statues, and the interior was often adorned with polished rocks and softer materials, such as coloured marbles, dark serpentine and white alabaster. Much information regarding building materials has been given in the Cantor lectures delivered by Professor Ansted* and by Mr. W. Y. Dent.† Large quantities of stone have also long been necessary for road making. The substances to which this lecture is devoted are, however, used for a great variety of purposes, for instance roofing slates, lithographic limestone, millstones, abrasives, the use of limestone, gypsum, fluor-spar and barytes in the chemical industries, and the increasing application of asbestos and mica in engineering practice. I may also remind you of the vast quantities of sand and gravel, of clay, fireclay and kaolin, that are used for mortar, bricks, pottery, porcelain, and glass manufacture. The economic importance of all these substances will be evident from a consideration of the quantities raised in the

United Kingdom alone. In 1902 the minera produce, according to Sir C. Le Neve Foster's report, included :—

	Quantity.	Value.
	Tons.	£
Barytes	23,608	22,414
Bauxite	9,047	2,679
Chalk	4,395,673	193,757
Chert and flint	99,344	17,413
Clay.....	15,304,136	1,758,884
Fluorspar	6,287	3,186
Gravel and sand.....	2,067,745	157,741
Gypsum	224,669	78,969
Igneous rocks	5,466,964	1,400,266
Limestone (other than chalk). 12,172,851		1,382,132
Mica	8,542	3,047
Ochre, umber, &c.	16,963	22,406
Phosphate of lime.....	86	109
Sandstone	5,483,130	1,798,879
Slate	517,363	1,501,789
Sulphate of strontia	32,281	32,281

These figures do not include statistics of quarries under 20 feet in depth.

In the United States the value of the entire stone production in 1901 was £12,196,000.

Flint.—In the Stone Age flint was mined for tools and weapons in the chalk in East Anglia, and mining still continues for the purpose of supplying gun-flints and ornamental stone for building. Even now the Brandon knappers make a considerable number of gun-flints for export annually. Regular workshops for the manufacture of tools from the chalk

* *Journal of the Society of Arts*, vol. 13, p. 251.

† *Ibid.*, vol. 35, pp. 825, 841, 855, 870.

flints also existed in the Stone Age in the island of Rügen, at Mons in Belgium, in Sicily, and at Seneca in Missouri. Sometimes red and yellow jasper and obsidian were employed. Hammers and wedges were usually made of diorite, gabbro, and serpentine, or of the tough minerals nephrite and jadeite. Quartzite and compact lava were sometimes used for hammers. Obsidian was largely used by the ancient Mexicans. The obsidian deposit is still known as "the mountain of knives" (*sierra de las navajas*). Obsidian was also worked in the Greek island of Melos, and it is still in use among the West Australian natives.

Sandstone.—Sandstone is the most important of building stones and is widely distributed. The finer descriptions of sandstone come under the head of freestone. The British sandstones used in building are derived from beds of Devonian, Carboniferous or Triassic age. Tintern Abbey is built of Devonian sandstone. The millstone grit supplies a useful building material as it resists the action of acid in smoky atmosphere. Sheffield parish church is a good example of its use. Fine-grained sandstones are used for carving and ornamentation, whilst coarse-grained heavy stones are used for foundations, engine-beds, docks, and sea-walls. Thin bedded sandstone is used as flagstone. Under the heading of sandstone in the British statistics are included quartzite, produced by the metamorphism of sandstone, and flint conglomerate, which are used in furnace construction; and ganister, a rock found in the lower coal measures at Sheffield, consisting chiefly of fine quartz grains, which is employed for lining Bessemer converters.

Sand, derived from the disintegration of rocks, is dug in many localities. Siliceous sand free from iron is used in the manufacture of glass, and is produced at Alum Bay, Isle of Wight, at Lynn, Norfolk, at Reigate, Surrey, and at Fontainebleau, France. Argillaceous sand is used as a moulding material in foundry practice. Sand of this kind is largely worked in Belgium, where at one of the most important deposits at Lommel 800 tons a day are pumped up and loaded mechanically on to barges. The installation is of special interest as it comprises the first electrically worked sand pump driven by an alternating current dynamo. The electric machinery is supported on rafts made of empty petroleum barrels and the delivery pipe of the centrifugal pump leading to the bins along the canal is also carried on

similar rafts. From the bins the sand is loaded by an electrically driven travelling elevator with endless chain into the barges. The delivery pipe of the centrifugal pump delivers the sand on to a coarse sieve to remove foreign material before entering the bins. In 1900 the production of sand in Belgium was 653,780 cubic metres, valued at £50,199.

Limestone.—Next to sandstone, limestone is the building stone most largely used. It is derived from beds of Devonian, Carboniferous or Oolitic age. The Devonian limestones are often crystalline and are largely quarried for marble. The Oolitic limestones are largely employed for building purposes, the Bath stone from the Great Oolite being the best known. Portland stone, from the Upper Oolite, was used for the west front of St. Paul's Cathedral (1700), and for Somerset House, the National Gallery, the Royal Exchange, the Tate Art Gallery, and the Law Courts. Caen stone from quarries in Normandy has been used in England since the time of the Norman conquest. The best known examples are the Temple Church and Winchester and Canterbury Cathedrals. Kentish rag, from the lower greensand near Hythe and Folkestone, has largely replaced Portland stone as a building material in London. It is much used in rubble work and also as a road material near Maidstone. Limestones free from phosphorus are used as a flux for iron smelting. Large quantities are also used in the production of quicklime for building purposes. The so-called Bath stone is mined at Corsham in Somersetshire. The bed varies from 8 to 24 feet in thickness with a dip of 1 in 33. It is mined by driving a main heading 16 feet in width from the inclined plane from the surface, with side holes at right angles 24 feet wide, leaving pillars 10 feet square. In order to remove the stone a horizontal groove is cut in for a depth of 5 feet and a width of 25 feet. Vertical cuts are then made with a saw, and the blocks detached by wedging. According to Sir C. Le Neve Foster a workman can saw 15 square feet in an hour.

In one respect limestone is unequalled, and that is in the preparation of lithographic stones, for which the Jurassic limestone of Solenhofen, in Bavaria, is specially suitable. It is exported to all parts of the world. In 1902 the production was 9,020 tons, valued at £35,957.

In fissures in limestone transparent crystals of calc-spar are frequently found. The best variety is the doubly refracting spar from Iceland, which is largely used for polarisation apparatus. Pure lumps are worth 28s. to

£5 5s. per pound. In Kent and Essex large quantities of chalk are quarried for use in the manufacture of Portland cement.

Marble.—Although marble, that is, limestone sufficiently compact to receive a polish, is of frequent occurrence, at the present time the marbles of Upper Italy and Greece are the most valued. In Italy the Carrara district is situated between Spezzia and Leghorn on the Mediterranean seaboard. The marble strata, beds of crystalline limestone of Triassic age, cover an area of 80 square miles, and reach in places the enormous depth of three-quarters of a mile. The mines, some of which were worked by the Romans 800 B.C., are surface workings at an altitude of 700 to 3,000 feet above sea level. The railway for transporting the marble, which I described in a previous lecture,* presents several points of interest. Owing to the rapid rise of the ground it was impracticable to send a separate branch up to each mine from Carrara, following the ancient water-courses occupied by bullock cart roads; and rope traction would have necessitated placing a powerful stationary engine at each of the nine mines. It was consequently necessary, with grades of 4 to 6 per cent., to have a series of reverse stations. The construction of the railway was a work of some difficulty, as there are 15 tunnels and 16 bridges and viaducts, the remainder consisting of cuttings and sustaining walls from 16 to 46 feet in depth. In the Carrara district there are now 611 quarries in operation, 345 of which are at Carrara and 50 at Massa. The number of persons employed in the marble industry in 1901 was 10,549. The quantity of marble shipped in 1901 was 290,570 tons, valued at £465,000. Of the shipments there were sent to

	Per cent.
United States	20
Great Britain	15
France	13
Germany	8
Spain and Portugal	5
Italy	20
Other countries	19
Total.....	100

Ordinary kinds fetch 4s. 3d. to 7s. per cubic foot, f.o.b. Leghorn. Better qualities for statuary fetch 15s. to 30s.

The helicoidal wire saw has been employed for quarrying marble at Carrara for some years. It is an endless cord, composed of three hard wires twisted together, which is made to travel

along by machinery and is fed continuously with sand and water, the sharp particles of sand gradually cutting a groove. As the groove is deepened the cord must necessarily be kept to the rock. This is effected by guiding-pulleys mounted in pits sunk at the ends of the proposed cut. These pulleys must be at least 20 inches in diameter, and the pits somewhat larger. In some quarries a rotative borer is employed for sinking these pits composed of a steel tube cutting an angular groove. The wire saw was applied at Carrara for subdividing blocks of marble, but the impracticability of using the revolving cylinder, or hand labour for sinking inclined pits, was an obstacle to its further use. The difficulty was, however, overcome by Mr. Monticolo, who invented an ingenious appliance which he termed a penetrating pulley, with which it is possible to replace the somewhat costly pit by a bore-hole 3 inches in diameter. The penetrating pulley consists of a disc 20 inches in diameter, and $\frac{1}{4}$ inch thick, with a semi-circular groove round its periphery, deep enough to take half the thickness of the wire, the other half projecting. The disc is mounted on a pivot, and is supported by a hollow steel shaft of slightly smaller diameter than the bore-hole. To the shaft is attached a series of tubes of equal diameter, forming a column that may be lengthened at will, in the interior of which is a fine tube, serving for the lubrication of the pivots. As the cut deepens the pulley is fed down automatically by means of an eccentric. For cutting a groove two bore-holes, to receive the shafts carrying the axes of the pulleys, are first made by hand or by the diamond drill. The pulley was first applied in March, 1898, at the Campanile quarry, Carrara, where cuts have been made 50 feet long and 16 feet deep, inclined at an angle of five degrees from the horizontal. The highly satisfactory results obtained with the penetrating pulley serve to show that there is a great saving of expense by the substitution of bore-holes for pits, far less waste of valuable marble, increased rapidity of quarrying, and consequently increased output. In Italy there are numerous other marble quarries worked on a smaller scale, notably those of the celebrated yellow marble of Jurassic age at Siena.

The marble wealth of Greece, famed in classic times, has been developed only during the past ten years. In 1894 Mr. Brindley rediscovered the original quarries of the genuine "Verde Antico," the most valuable marble of antiquity, near Larissa in Thessaly, after

* *Journal of the Society of Arts*, vol. 40, p. 825 (1892).

having lain idle since the time of the Emperor Justinian in the 6th century, and a company was formed in 1896 (the Verde Antico Mining Co., capital £20,000), to work these famous quarries. It is believed that the columns of St. Sophia, Constantinople, and the decorations in St. Mark's, Venice, were obtained from these quarries. An English company formed in 1897 (Marmor, Ltd.), owns the Pentelikon quarries near Athens, from which the columns of the Parthenon were extracted. Perhaps the largest ancient quarries are those of Styra in Eubœa. The marble, which is much esteemed at present, can be obtained in almost any lengths. It has been used for the Belfast Town Hall. The quarries of the island of Paros, which supplied the Parian marble from which the Venus of Milo in the Louvre was carved, have not yet been satisfactorily reopened. Nearly all the known marble quarries in Greece are owned by Marmor, Ltd., a company formed in 1897 with a capital of £350,000. Its output has increased from 2,244 tons in 1897 to 15,920 tons in 1902. The mechanical equipment of the quarries is excellent, especially at Pentelikon, where there is a large steam saw mill. The marble which is worked by the wire saw is transported down self-acting inclines, a seven-mile railway connecting with the main line. The Verde Antico Marble Company, Ltd., founded in 1896 with a capital of £20,000, also works its quarries in Thessaly with the wire saw, and exported 500 tons in 1902. The total production of Greek marble in 1902 was 17,220 tons. A map showing the various marble areas in Greece has been prepared by Mr. Percy Bennett, of the British Legation at Athens. Belgium is also an important source of marble. The centre of the industry is in Namur, the beds being of Devonian and Carboniferous age. In Austria, the Tyrolean marble has long been esteemed for statuary purposes, the size of the block, the purity and uniformity of grain being remarkable. From a quarry in this district a magnificent white block was raised in 1902 for the Von Moltke monument in Berlin. It measured 1120 cubic feet and weighed 85½ tons. In France and Spain there are some important marble deposits in the Pyrenees and in the Sierra Morena. Coloured marbles are produced at a low price in Norway. A bed of various colours, 1,000 yards thick, occurs at Dunderland, where an important iron ore industry is being started. The marbles of Great Britain are mainly of Devonian and Carboniferous age. "Many mines of coarse and fine marble," wrote

Holinshed in 1577, "are there in England; but chiefly one in Staffordshire. Of white marble also we have store. The black marble spotted with green is none of the vilest sort." The collection of Irish building materials exhibited at the Imperial Institute in May, 1903, showed that Ireland possesses a great variety of marbles of great beauty of colour. In the United States the marbles of Vermont are largely quarried, whilst in Mexico the celebrated onyx marble is the basis of an important industry. The value of the marble production of the principal countries in 1901 may be summarised as follows:—

Italy	1,000,000
United States	650,000
France	198,480
Belgium	107,000
Mexico	21,750
Other countries	1,800,000

The great examples of the decorative use of marble are St. Mark's at Venice and St. Sophia at Constantinople, and in both the finest specimens are known to have been plundered from the older buildings. The remarkable variety in the marbles used for decorative purposes can be seen in a striking manner in the new Westminster Cathedral. Sixty specimens of marble from different parts of the world were procured, after great research, by the architect, Mr. W. Brindley. In the crypt the columns are of red Norwegian granite, with capitals of Hopton Wood marble and Derbyshire marble bases. The 29 columns on either hand of the nave, with capitals of Carrara marble, are of *verde antico*, of Greek *cippolino* (white marble with green veins) from Eubœa, Swiss *cippolino* from Saillon in the Rhone Valley, Italian breccia from Serevazza, grey granite from Norway, and red granite. These shafts, 13 feet long, each stand on a base of Norwegian granite.

Dolomite and Magnesite. — Magnesian limestone or dolomite is largely used in the manufacture of Epsom salts, and, when calcined, as a lining for basic steel furnaces. The massive and granular varieties are quarried as building stones in Yorkshire, Derbyshire, and Nottinghamshire. This stone from quarries at Bolsover, Derbyshire, and at North Aston was used for the Houses of Parliament. For lining steel furnaces dolomite has to be dead-roasted until all the carbonic acid and water are removed. For this purpose magnesite, native magnesium carbonate, is frequently used, and would be exclusively used if the

supply was not limited and the price correspondingly high. It occurs in thick beds in Styria, in Euboea, in Hungary, at Frankenstein at Krubschitz in Moravia, at Snarum and in California and Texas. The ty occurs in the Salem district in lia. From unpublished information shed by Mr. H. G. Turner, a member of the mines, we learn that the deposits (Fig. 9) are situated two miles or more from the port of Madras, at a distance from the port of Beypore coast. The depth of the deposit is 47.35 per

ture of fire-bricks, and for linings and hearths for steel furnaces, excellent results have been obtained. Magnesite bricks now on the market are deficient in refractory qualities because the minerals in which they are made contain too great a proportion of other ingredients. Thus the Hungarian magnesite contains 3.2 per cent. of ferrous oxide, and the Grecian magnesite contains 4.02 per cent. of carbonate of lime. Nor are these magnesites properly dead-burnt or shrunk before being made into bricks, so that these bricks contract and lose shape when subjected to great heat, as in metallurgical processes, where bricks of stable

FIG. 9.



MAGNESITE DEPOSIT, SALEM.

cent. of magnesia, 51.44 per cent. of carbonic acid, 0.30 per cent. of ferric oxide and alumina, and 0.27 per cent. of moisture, 0.22 per cent. of insoluble siliceous matter and no lime. Its specific gravity is 3.056. It is quarried and ground in mills of primitive construction (Fig. 10). Numerous experiments have been made to discover a simple process for making a plaster cement from this substance. It affords, when properly treated, a permanently hard white or coloured plaster which takes a brilliant polish; it is also suitable for tiles, artificial stones, and covering for floors, terraces, walls, and roofs. It is impervious to damp and is a protection against heat, advantages of extreme importance in its use in tropical countries. In the preparation of the magnesite for the manufac-

quality are indispensable to prevent constant renewals and repairs. In order to produce a good magnesite brick, that is, a brick consisting essentially of pure magnesium oxide, it is necessary, not only to dead-burn the crude material, but to subject it to such an intense heat as to cause it to crystallise. Mere calcining in a cupola, or even in a Siemens' furnace, cannot effect this physical change in the condition of the substance. The only heat which can do this is that of the electric furnace, and Indian magnesite is pure enough to undergo the ordeal. Recent experiments made on a considerable scale show that under the intense heat of this furnace, the Indian mineral crystallises into a hard, dense mass, yielding a product of the greatest refractory quality,

which is not only adapted to the manufacture of bricks, but, when powdered and mixed with some adhesive material, it affords a paste and a mortar sufficient to protect the brick walls of furnaces from attack. For instance, it has been found that when the fire-bricks lining a melting pot in a calcium-carbide furnace were fixed with mortar and covered with a wash of this crystallised and ground magnesite they lasted for 200 hours without repair, whereas the unprotected bricks required repair after a five hours' heat. This crystallised mass itself, without further preparation than being crushed

calcining the ore, which required a large quantity of fuel. In recent years, however, modern shaft calciners have been built, and a soft lignite coal is used. Magnesite is used in the crude state for manufacturing carbonic acid, for whitening paper pulp, and for whitening wool. Its selling price f.o.b. Greece is about 14s. per ton raw, and £2 10s. calcined. In 1900 Greece produced 17,277 tons valued at £13,822, and the United States in 1901 produced 11,953 tons valued at £8,611.

In association with magnesite in Asia Minor the hydrated magnesium silicate, meerschauum,

FIG. 10.



GRINDING MAGNESITE, SALEM.

to suitable dimensions, will, it is thought, prove of special value as a refractory material in metallurgical practice. An important point in connection with its use as linings for electric furnaces is that magnesite, unlike lime, does not form a carbide with carbon.

The deposits of magnesite in the Island of Eubœa are among the largest and richest known. Quarries are worked by the Anglo-Greek Magnesite Company, Ltd., the output in 1901 being 13,000 tons of raw and 2,100 tons of calcined magnesite. The company has ten kilns in operation, and can turn out about 70 tons of calcined magnesite a day. At the Greek magnesite mines until recently, roughly built kilns fired by wood were employed for

occurs in soft nodules and reniform masses. Large quantities are sent to Vienna and Paris to be carved into pipes.

Slate.—Among the sedimentary rocks, slate is of the greatest value. It is used for roofing purposes, as well as in large slabs for billiard-tables, cisterns, steps, &c., and for minor purposes such as school slates and pencils. The best slate is obtained from North Wales, where it has been worked since the 16th century. Three-fifths of the Welsh slate is produced from open quarries, and two-fifths from underground workings. The largest open quarries are Lord Penrhyn's, near Bangor, and those at Dinorwic, near Carnarvon, whilst the largest underground workings are those belonging to the Oakeley Slate Quarries Company, Ltd., at

Festiniog. The principal bed is 120 feet thick, and this thickness has necessitated the excavation of vast chambers, some of which are 100 feet high and 50 feet wide. Some remarkable photographs of these chambers at the Oakeley and Llechwedd mines have been made by Mr. J. C. Burrow, and will be remembered by visitors to the exhibitions of the Photographic Society. The method of working the slate is roughly as follows:—A main incline tunnel is driven from the top of the bed, and from this tunnel cross tunnels, termed floors, are driven right and left. Each of the floors is divided up into pillars and chambers, the average depth of each chamber being 50 feet. At Rhiwback, Mr. H. Humphris has introduced an ascending method of working in which all the rock available is procured at low cost. Small cross levels, 4 feet wide and 8 feet high, are driven at right angles to the main level. As soon as two of them are 25 to 30 yards long, the rock between is undercut by the wire saw, and top cut at a height of 6 feet above. The block is sliced off and rough dressed underground. The waste produced is stacked up to the level of the roof so as to form the floor of the next gallery. At Labassère, in the Pyrenees, the wire saw is employed to make horizontal cuts across the inclined beds of slate, severing great blocks without blasting. Believing that a similar system could be employed with advantage in North Wales, Sir C. Le Neve Foster recommended that Mr. G. J. Williams, Assistant Inspector of Mines, should study the question on the spot. The Home Secretary having acceded to this suggestion, Mr. Williams drew up a very valuable report, which was published in 1900. The investigation clearly showed that slate might be worked in many quarries in North Wales by the wire saw method with great advantage. There would be less blasting, fewer falls of ground, less waste of good rock, reduced cost of working, less cost of explosives, a saving in the cost of unproductive work, a saving in the cost of removing rubbish, no need for quarrying worthless rock in underground workings, and the cost of examining and securing the roofs and pillars would be done away with. In Cornwall the Delabole quarries have long been celebrated for the production of slate of good quality.

In Ireland there are some good slate deposits that have only been holed to supply slates for local use. Some of these appear as if they might be profitably opened up, although Irish

slates, as a rule, are heavier and not of as good a colour as the Welsh.

On the Continent slate is quarried at St. Goar, Rüdesheim, Oberwesel, and Andernach on the Rhine, in the Hartz, at Erfurt in Saxony, in Austria near Teschen, while in France, the Angers slate quarries are the most celebrated. There some 3,000 workmen are employed, and some of the workings are more than 900 feet deep. Devonian rocks are largely quarried for slates in the French Ardennes at Deville, Fumay, and Rimogne. The production of slate and slate slabs in France in 1901 was 289,812 tons, valued at £694,800.

Eruptive Rocks.—Eruptive rocks are extensively used for road metal. Granites, syenites, and diabases appear to be the best for the purposes. Granite has been used for constructive purposes from the earliest times. From the quarries of ancient Egypt were hewn the monolithic obelisks, which have been carried from their ancient sites to adorn London, Paris, and Rome. The British granite districts are in Devon, Cornwall, the Channel Islands, Lundy Island, Mount Sorrel in Leicestershire, and Shap Fell in Westmoreland. The granite of Devon and Cornwall has been largely used in London, notably for Westminster, Waterloo, and London bridges. The Duke of Wellington's sarcophagus in St. Paul's Cathedral is made of red granite from Luxulion, in Cornwall. The Mount Sorrel granite is pre-eminently suited for road metal. The Scotch granites are better, in that the quartz is more uniformly distributed. The granite districts of Scotland are in Aberdeen, Peterhead, and the Island of Mull, in Argyllshire. The Peterhead rich pink granite is largely used for ornamental purposes as in the pillars of the Carlton Club. The granite districts of Ireland are in Wicklow, Galway, Mayo, Donegal, and Down. The largest quarries are those near Dalkey. The polishing of granite has been fully described by Mr. G. W. Muir.* In former times basalt was largely used as road metal. The columnar structure of this rock, so picturesquely shown at Fingal's Cave, and at the Giant's Causeway, facilitated to a certain extent the comminution of the material. The use of basalt as road metal has, however, decreased owing to its becoming slippery with wear. Like basalt, the greenstones and whinstones are ill-adapted for building purposes, owing to their great hardness and sombre colour. Their principal uses

* *Journal of the Society of Arts*, vol. 14, p. 471.

are for paving and road metalling. The most important quarries are at Bardon Hill, Leicestershire, and Penmaenmawr, North Wales.

Of the rocks that are chiefly used for interior decoration and for the manufacture of decorative objects, serpentine, owing to the variety and beauty of its colours, is the most important. It is usually of a dark green or red colour. It is believed to be an alteration product of other rocks, and in composition is a hydrous magnesium silicate. It is largely worked in the Lizard district of Cornwall, at Zöblitz in Saxony, and at Espinal in the Vosges. At Zöblitz the bed extends for two miles with a thickness of twenty yards, in gneiss, and has been quarried since the 15th century.

Mica.—As one of the constituents of granite and other rocks, mica is widely distributed, and it has many industrial uses. The earliest use of mica was probably, under the name of Muscovy glass, for window panes. It is now chiefly used as a transparent medium unaffected by a sudden exposure to heat, in the doors of stoves, in the peepholes of furnaces, and as lamp chimneys. The largest quantity is used for electrical purposes for covering portions of dynamos, and in India for decorative purposes. The waste scrap is turned to account as a lubricant, as electric insulator, as non-conducting packing, and in paper manufacture. Large crystals form a valuable product. Clear crystals measuring 8 inches square fetch 18s. per lb., and scrap mica 13s. per cwt. A single crystal from North Carolina has been known to weigh nearly a ton. The world's supply is obtained from India, the United States (North Carolina and New Hampshire), Canada (Quebec), and Brazil. Small quantities are also raised in Norway, Siberia, and China.

In India, mica mining is an industry of considerable importance. In 1900 there were 131 mines, employing 9,517 persons, at work on mica. The total output amounted to 916 tons, more than half of which was raised in the Nellore district, Madras, which is now outstripping Bengal in the development of its mica resources. The Indian mica deposits have been well described by Mr. T. H. Holland, of the Geological Survey of India. He shows that the mineral, Muscovite mica, occurs as a constituent of granite pegmatite. Crystals have been obtained in the Nellore district measuring 10 feet across the basal planes, but usually they are much smaller. In the Imperial Institute collection there is a

crystal 3 feet by 2½ feet, weighing 64 lbs. The pegmatites worked for mica have intruded into the schists in the form of sheets following the foliation, or less frequently as dykes cutting the schist obliquely. The system of mica mining carried on, like that under European management, is of the wasteful and primitive type possible. In the Bengal area the mines are narrow irregular holes following the mica from crystal to crystal, sometimes to depths over 200 feet. All materials are brought to the mouth of the hole, often near the top of a hill where a pegmatite outcrop was originally discovered (Fig. 11.) Mining has to be suspended in the rainy season, and an hour is spent each morning in baling out the water accumulated overnight. In Nellore the mineral is raised

FIG. 11.



ENTRANCE TO MICA MINE, HAZARIBAGH DISTRICT. (Photographed by T. H. Holland).

open quarries, the slope of whose sides is determined by the angle of repose of the surrounding schists. That mica mining has yielded large profits in these circumstances indicates the value of the deposits, and suggests that with a more rational system of mining of the abundant mineral still available, India should continue to hold its place as the leading mica-producing country. The mica sheets are trimmed by cutting off the broken and flawed edges, and are sent to the London market in sheets of irregular shape. An important part of the dressing operations consists in splitting the mica to remove inclusions of foreign minerals that would, if allowed to remain, lessen the value of the sheet. Cutting into rectangular sheets is but little practised owing to the lower duty on unmanufactured mica imported into the United States.

In the United States mica is obtained

in North Carolina from veins of giant granite, 30 feet wide, in mica schist. Mica also occurs in workable quantities in Brazil. The deposits, which have been described by Mr. H. Kilburn Scott, are pegmatite veins, lenticular masses or dykes, occurring in metamorphic schists. In Cornwall mica is obtained as a by-product in the preparation of China clay, the amount yielded in 1901 being 3,216 tons valued at £1,266. During that year the Indian production was 1,159 tons, valued at 995,192 rupees. The United States produced 360,060 lbs. of sheet mica, valued at £19,752, and 2,171 tons

10,330; and Canada, 4,741 tons, valued at £968.

Clays.—From the decomposition of the soda-felspar in granite, kaolin or china clay is obtained. It is the purest variety of clay, and is largely worked for the pottery at St. Austell, in Cornwall. The kaolin is separated when the soft, altered granite is washed down by a current of water. The rise and progress of the industry was dealt with in great detail in a paper read before the Society by Mr. J. H. Collins* in 1876. The amount shipped from Cornwall in 1902 was 562,502 tons.

FIG. 12.



DIGGING CLAY, RAEVELS, BELGIUM.

of scrap mica, valued at £3,944. The value of the Canadian output was £32,827.

Felspar.—Another constituent of granite and other rocks, of great economic importance is felspar. Orthoclase or potash felspar, is largely used for the manufacture of porcelain. It is quarried at Trenton, New Jersey, and at East Liverpool, Ohio, and considerable quantities are raised in Norway and Bohemia. The prices varies from 10s. to £1 per ton. In 1901 the United States produced 31,525 metric tons of felspar, valued at £44,084; Norway, 17,609 tons, valued at £6,400; Sweden 15,228 tons, valued at

For the manufacture of bricks, clay is worked in large quantities in the United Kingdom. Fire-clay is largely mined in the coal measures, forming the under-clay of some of the seams. Devonshire and Dorsetshire yield pottery clays of Lower Tertiary age. Bedfordshire and Surrey yield fuller's earth from the Lower Greensand, and Somersetshire yields it from beds of Jurassic age. In the United States the plastic clays of New Jersey, and most of the brick, tile, and terra cotta clays of Delaware, Maryland, and Virginia, are of Cretaceous age. The United States output

* *Journal of the Society of Arts*, vol. 24, p. 565.

of clay products (bricks, tiles, and pottery) in 1901, is valued at £22,000,000. The output of clay was 1,367,170 tons, valued at £515,000. On the continent clays are extensively worked. In the north of Belgium there is, in a series of alternating beds of blue or grey compact clay and sands, a bed 3 to 20 feet thick of clay of remarkable plasticity, the composition of which renders it specially suitable for the manufacture of artificial Portland cement. It is used for that purpose by six of the ten cement works in Belgium. The clay worked at Raevens (Fig. 12) has, when dry, the following composition:—

Silica	65·25
Alumina	21·10
Ferric Oxide	5·20
Lime	1·20
Magnesia	0·50
Alkalies	0·10
Loss on ignition.....	7·65

Gypsum.—Gypsum consists of calcium sulphate with 21 per cent. of water. It forms great masses in stratified rocks. In England, it is mined in Nottinghamshire, Staffordshire, and Cumberland, from beds of Triassic age, and in Sussex, from a seam belonging to the Purbeck beds. More than half the world's supply is produced in France, where gypsum of Tertiary age from the Montmartre quarries, Paris, is used as building material. The world's production in 1901, was as follows:—

	Metric tons.
France	1,991,000
United States	598,602
Canada	266,531
United Kingdom	203,988
Switzerland.....	45,987
Germany	39,000
Cyprus	5,373
India	4,415
Italy (alabaster)	2,714
Mexico.....	1,600
Algeria.....	600
Greece	82
	3,159,892

In its transparent crystalline state gypsum is known as selenite. When it presents a finely fibrous appearance it is termed satin-spar, and is used for beads, the best quality being worth about £7 a ton. When resembling white marble it is known as alabaster, and is worked mostly in the Volterrano district in Tuscany into vases, statuettes, and other artistic objects. When calcium sulphate is not combined with water it is anhydrite, a rock likely to absorb water and pass into gypsum.

Ordinary gypsum is chiefly used for the manufacture of plaster of paris and cements, and as a fertiliser. Some 350,000 lbs. are, according to Mr. A. T. Metcalfe, annually used for the Burtonising of beer. The mode of formation of gypsum deposits is thought to have been as follows: In salt lakes, water is evaporated, and as it becomes concentrated, salt and gypsum are precipitated, forming solid masses at the bottom; gypsum being less soluble than salt, is precipitated first. The process can be observed at the Dead Sea and at the Great Salt Lake.

Sulphur.—By the reducing action of organic matter on sulphate of lime (gypsum) sulphur is formed. This explains the origin of the celebrated sulphur deposits of Sicily which occur in Miocene limestone, with the unaltered beds of gypsum below. Other deposits of sulphur in Japan, Mexico, Utah, California, Nevada, and Alaska are products of volcanic activity, as also are the Iceland deposits described by Mr. Vincent.* The deposition of sulphur may be seen in progress at La Souffrière in St. Lucia, West Indies. In Louisiana there are deposits resembling those of Sicily. The world's production of sulphur in 1900 was as follows:—

	Metric tons.	Per cent. total.
Italy	544,119	94·0
Japan	14,435	2·5
France.....	11,551	2·0
United States.....	3,199	0·5
Germany.....	1,420	0·2
Greece	891	0·1
Austria	862	0·1
Spain	750	0·1
Russia	451	—
Hungary	123	—
Sweden	70	—
World's total.....	577,420	100·0

The value of the world's production is estimated at £2,139,696. Sulphur has been used as a disinfectant since the earliest times. In the *Odyssey* (Book xxii.) after Ulysses had slain the suitors:

“To Euryclea then address'd the king:
‘Bring hither fire, and hither sulphur bring
To purge the palace.’”

In the manufacture of sulphuric acid sulphur is now largely replaced by iron pyrites. The chief use of sulphur is now for dressing vines, and in the manufacture of paper by the

* *Journal of the Society of Arts*, vol. 21, p. 137.

sulphite process in which wood pulp is digested under pressure with sulphurous acid. In Sicily the sulphur mines are distributed over a wide area near Girgenti in the south of the island, the sulphur occurring in a bed of Upper Miocene limestone in places as much as 164 feet thick. The methods of mining are of a primitive description, the crude rock being carried to the surface in sacks, up winding staircases by boys. The shipments of sulphur from Sicily, amounted in 1902 to 467,319 tons: There were 734 mines in operation, and 32,604 miners were employed. For the extraction of sulphur the old process of liquation in kilns has now been largely superseded by improved methods in furnaces and steam apparatus. Last year the kilns yielded only 38·01 per cent. of the total output. The world's stock of sulphur is now practically held by the Anglo-Sicilian Sulphur Company, Ltd. (paid-up capital, £735,000), which made for the year ending July 31, 1903, gross profits of £154,649. In the United States the production of sulphur in 1902 was 8,336 tons, valued at £44,112. The imports during that year represented a value of £656,127, Sicily supplying 163,571 tons valued at £622,394.

Asbestos.—In commerce, under the name of asbestos, two distinct minerals are known, namely amianthus, an anhydrous silicate, a brittle fibrous hornblende that is not acted upon by acids, and chrysotile or serpentine asbestos, a hydrated compound that is acted upon by acids, but is characterised by the great elasticity of its fibres. The properties of these minerals have been fully described by Mr. J. Boyd* and by Mr. Robert H. Jones.† The first of these minerals occurs principally in Italy and Austria, while the latter is produced mainly in the province of Quebec, Canada. Both minerals may be easily divided into fine fibres which can be spun like cotton. The waste material is compressed, or when powdered it forms the basis of fire-resisting paint. Among the economic minerals of Canada, asbestos takes the first rank. Whilst in 1880 the production was only 380 tons, in 1901 it was 38,500 tons, representing a value of £300,000. In that year the world's production included :—

	Tons.
Canada	34,545
Russia	3,845
United States	678
Italy	300
Tasmania	90
Cape Colony.....	89

* *Journal of the Society of Arts*, vol. 34, p. 582.

† *Ibid.*, vol. 45, p. 543.

In Canada asbestos is mostly obtained in quarries. The better sorts are picked out by hand. The first sort has fibres of over $1\frac{1}{4}$ inches in length, whilst the second is $\frac{1}{4}$ to $1\frac{1}{4}$ inches. The poorer qualities known as "fibre" and "paper stock" are produced by mechanical dressing. The Danville Co. pulverises the waste, and with a certain addition of serpentine obtains asbestic, a product now largely used for fire-proof buildings. According to Mr. F. Cirkel, 100 tons of mineral raised yield $1\frac{1}{2}$ tons of crude and 5 to 8 tons of fibre and paper stock. The price is :—

	Per ton (dols.).
First sort crude.....	180-200
Second sort crude.....	100-128
Fibre	30-60
Paper stock	20-28
Asbestic.....	2-4

The production of the different qualities in 1901 was :—

First crude	2,083 tons.
Second crude	2,660 "
Fibre	14,659 "
Paper stock	14,054 "
Asbestic	6,831 "

In the Thetford Black Lake district there are at work twelve great companies with a capital of over four million dollars. The industry affords employment to 3,000 workmen, who earn 4s. 7d. to 5s. for a ten-hour shift. The largest company is Bell's Asbestos Co., Ltd., with a paid-up capital of £120,000. This company employs 400 workmen at its mines at Thetford, and is equipped with machinery of the latest type; it also has a first-class plant for the mechanical separation of asbestos. Johnson's Co., Ltd., incorporated in Quebec, in 1885 (capital 250,000 dols.) is the oldest company at Thetford, and produces asbestos of specially good quality.

Bauxite.—The hydrate of aluminium, identified by Berthier, in 1821, at Baux, near Arles, and named in consequence bauxite, is now largely worked for the manufacture of aluminium, and as a fire-resisting material. In Ireland it occurs with beds of iron ore between sheets of tertiary basalt in County Antrim. The bulk of the world's supply is, however, obtained from the United States and France. At Baux it occurs in masses in the chalk. The world's production, in 1901, was as follows :—

	Metric Tons.
France.....	76,620
United States	19,205
Ireland	10,355
World's total.....	106,180

In the United States, Georgia yields the bulk, the remainder being obtained from Alabama and Arkansas. The Arkansas bauxite occurs in the Fourche Mountain district and in Bryant township. At Bryant, it rests on kaolinised syenite, and has a thickness of about fifteen feet. Some of it is pisolitic, while the whole is of this character in the Fourche Mountain district. The deposits appear to have been due to the action of heated alkaline water on the syenite, and to subsequent superficial chemical reactions on the deposits left by the springs.

Other Earthy Minerals.—There are numerous other useful earthy minerals, some of which may be briefly mentioned. Minerals used as abrasives, oilstones and whetstones, grindstones and buhrstones, are in increasing demand from year to year. Some of these, crystalline quartz, garnet, corundum, and emery, will be incidentally noticed under the head of precious stones. In the United States, the total value of all the natural abrasives produced in 1901 was £297,000. Infusorial earth, or kieselguhr, is largely used as a polishing powder as well as an absorbent for nitro-glycerine in the manufacture of dynamite. It is also used as a non-conductor of heat for coating steam-pipe. It is a siliceous earth, consisting entirely of the microscopic shells of diatoms. It is found in the Lüneberg Moor in Hanover, in the Siegen district, in Scotland, and in Italy. In the United States, the most important deposit is at Red Mountain in Nevada. Pumice is also used for polishing. It is a glassy lava, rendered porous by the escape of gas through its mass when in the state of fusion. The most important source of supply is the Lipari Islands, which exported 6,834 tons in 1901. The deposit covers about 3,706 acres. Monte Pelato, the centre of the industry, is an extinct crater, on which the accumulations of pumice reach in places a thickness of 650 feet. All material is now got from extremely primitive underground workings in a bed 3 to 12 feet thick. About 1,200 persons are engaged in the industry. In 1901 the production was 8,300 tons, valued at £31,000. In the mineral paint industry, there are several raw materials that may here be mentioned. The ochres, which

consist chiefly of ferric hydrate, are largely used, while the clayey ferric oxide, bole, gives the well-known bright red colour. The world's production of ochre in 1901 included:—

	Tons.
France	36,454
United States	16,711
United Kingdom	16,287
Germany	12,681
Canada	2,233
Cyprus	1,098
Belgium	330
Spain	64

The pumice sands and tuffs of the Eifel, known as trass, are used for making mortar, as is also puzzuolana, the volcanic ash that is quarried at the foot of Vesuvius. In the small group of useful minerals, not ores, occurring in mineral veins, barytes, fluorspar and strontianite are of considerable value.

In the United Kingdom, barytes or heavy-spar is obtained from veins in Silurian rocks, or in the carboniferous limestone in three principal districts—Northumberland, Shropshire, and Ireland. The first supplies witherite, the carbonate; and the second and third, mainly heavy-spar, the sulphate. In the United States, this mineral is widely distributed. It is used chiefly for adulterating white lead paint. The world's production in 1901, included, in metric tons:—United States, 44,516; Germany, 88,000; United Kingdom, 28,054; Belgium, 22,800; Canada, 592. Fluorspar is mined in Derbyshire under the name of "Blue John." It is used as a flux in smelting operations, in the manufacture of hydrofluoric acid for etching glass, as a glaze for pottery, and in the manufacture of opalescent glass. By far the largest amount is used in fluxing iron. In 1901, the world's production comprised, in metric tons:—United States, 17,768; Germany, 29,000; United Kingdom, 4,232; France, 3,970. Sulphate of strontium is dug from shallow pits in Gloucestershire and Somersetshire. It is found in the red marl belonging to the Keuper beds. The chief supply is obtained from Hamm, in Westphalia, where seventeen mines, in 1901, produced 1,020 tons, valued at £73,875. There is small demand for the mineral. It is used by firework makers and in the treatment of beet sugar.

LECTURE IV.—DELIVERED DECEMBER 14, 1903.

Precious Stones.—Diamond—Corundum gems—Emerald—Other precious stones—Ornamental stones—Rare earths.

PRECIOUS STONES.

The properties of precious stones have already been dealt with in a course of Cantor Lectures by Professor H. A. Miers,* and important papers on the subject have been contributed to the Society by Professor A. H. Church,† by Mr. A. Phillips,‡ and by Mr. C. Giuliano.§ I need, therefore, in this lecture say but little regarding the mineralogy and the artistic interest of precious stones. Most of the precious stones have been known from the earliest periods of antiquity. Four magnificent bracelets of gold set with amethyst, turquoise, and lapis-lazuli, to which a date as remote as 5,000 B.C. is assigned, were found by Professor Flinders Petrie in his recent excavations at Abydos. The twelve stones on Aaron's breast-plate, engraved with the names of the twelve tribes, if it were possible to identify them with certainty, would still be regarded as precious. In early times, such stones were highly prized, not only as objects of ornament, but as charms possessing medicinal virtues; indeed the use of precious stones as jewellery appears to have arisen primarily from the magic powers attributed to them, by which they were thought to protect the wearer. Writing in 1644, Boetius de Boodt in his "Histoire des Pierreries," suggests that the substance of the gems, in consequence of their beauty, their lustre, and their dignity, is considered suitable for the dwelling and receptacle of good spirits; and thus when marvellous effects are produced by the precious stones, they should be attributed not to their inherent properties, but to the spirits. The jewellery of primitive people consisted of small stones with natural perforations. Later on, they learned

to bore hard stones. As an example, I may mention the perforated chrysolite shown in a drawing in the "Hortus Sanitatis" of 1490. In this work, it is asserted that chrysolite drives away demons and the worst melancholy fears if pierced, and the hole filled up with ass's bristles, and the stone bound on the left arm. Even in pre-historic times precious stones were bored and worn as beads. In Mexico, for example, amazon-stone, chrysoprase, amethyst, red jasper, and brightly-coloured fluorspar were used. In Central Europe, amber was the earliest gem. Soft soapstone, which can be polished with the hand, was also worked into beads.

As a group, precious stones are chiefly distinguished from other minerals by their transparency, lustre, hardness, colour, specific gravity, electric properties, refractive power, and symmetrical crystal form. They are found disseminated through rocks, in veins, fissures or cavities, or in alluvial deposits derived from the disintegration of rocks. The esteem in which precious stones are held for use as personal jewellery does not decrease. Indeed, in the United States, the year 1902 showed the greatest importation on record of precious stones. According to statistics collected for the Government by Mr. G. F. Kunz, the production in the United States in 1902 was as follows:—

	£.
Turquoises	26,000
Sapphires	23,000
Tourmaline	3,000
Quartz-crystal	2,400
Chrysoprase	2,000
Beryl	800
Amethyst	400
Emerald	200
Other stones	5,860
Total	63,660

The following Table indicates the colours, degree of hardness (according to Mohs' scale),

* *Journal of the Society of Arts*, vol. 44, pp. 757, 769.

† *Ibid.*, vol. 29, p. 440.

‡ *Ibid.*, vol. 35, p. 438.

§ *Ibid.*, vol. 37, p. 391.

and specific gravity of the principal precious stones :—

	H.	Sp. Gr.	Colour- less.	Red.	Yellow.	Green.	Blue.	Violet.	Brown.	Black.
Diamond ...	10	3.5	—	—	—	—	—	—	—	—
Ruby	9	4.0	—	—	—	—	—	—	—	—
Sapphire ...	9	4.0	—	—	—	—	—	—	—	—
Chrysoberyl	8½	3.7	—	—	—	—	—	—	—	—
Topaz	8	3.5	—	—	—	—	—	—	—	—
Spinel	8	3.6	—	—	—	—	—	—	—	—
Emerald ...	7½	2.7	—	—	—	—	—	—	—	—
Zircon	7½	4.6	—	—	—	—	—	—	—	—
Garnet	7	3.8	—	—	—	—	—	—	—	—
Cordierite	7	2.6	—	—	—	—	—	—	—	—
Tourmaline	7	3.1	—	—	—	—	—	—	—	—
Quartz	7	2.6	—	—	—	—	—	—	—	—
Chalcedony	6½	3.1	—	—	—	—	—	—	—	—
Opal	6	2.3	—	—	—	—	—	—	—	—
Turquoise	6	2.7	—	—	—	—	—	—	—	—
Nephrite ...	6	3.0	—	—	—	—	—	—	—	—
Lapis-lazuli	5½	2.4	—	—	—	—	—	—	—	—
Malachite...	3½	3.9	—	—	—	—	—	—	—	—
Amber	2½	1.1	—	—	—	—	—	—	—	—

Diamond.—The diamond is the hardest substance known. It is, however, very brittle. Chemically it is pure carbon; it is combustible, infusible, and unassailable by acids. In the rough form it is devoid of brilliancy and is only semi-transparent. It is usually cut in one of the three forms, termed the brilliant, rose, and table, the first being the best for developing all its beauty. The double-cut brilliant was formerly square with a high crown, but with the advent of the South African stones and the American cutter the brilliants were cut round with a rather flat crown. Recently in America a modification of the rose brilliant forms of cutting with twenty facets, has been patented under the name of 20th century cutting. Besides their use in jewellery and glass-cutting, diamonds have numerous industrial applications. They are used for jewelling watches, 100 or 200 of them, when prepared for this purpose, weighing only one carat ($3\frac{1}{3}$ grains or $205\frac{1}{2}$ milligrammes). Diamond powder is used for drilling and polishing. Mounted diamond points are used for engraving, and the black variety is used for the cutting of millstones, and in the crown of rotatory rock drills. Recent researches have shown that the rays emitted by radio-active bodies induce fluorescence in diamonds. In this way, diamonds can be distinguished from other precious stones. Years ago, the fluorescence of diamonds under the influence of various coloured rays was noted, and Chaumet has ascertained that there is a close relationship between this fluorescent pro-

perty and the brilliancy of diamonds under artificial light, particularly candle light, which brings out most clearly the quality of first-class stones. The most sparkling stones show a notable fluorescence of a very luminous and clear blue. In a jewel-case in which are grouped diamonds of all qualities, the gems when illuminated by violet light, assume different tints from a vivid blue to sombre violet. As soon as the light is removed all degrees of phosphorescence are noticeable, the jewel-case appearing to be studded with glow-worms, some very bright, others almost extinct; the most sparkling stone will be found to be the best.

The origin of the diamond has long been a matter of discussion. It seems probable that diamonds have been formed by crystallisation from molten rock masses. Minute crystals of diamond have been found with graphite in slowly-cooled steel, and in meteorites. Mr. E. F. Heneage has arrived at the conclusion that the diamonds of South Africa were formed at a very great depth in the various pipes from accumulations of carbonic acid. The difficulty of reproducing these conditions of great heat and pressure artificially has been overcome by Professor Moissan, who found that iron, at a high temperature and under great pressure, will act as a solvent for carbon, and will allow it to crystallise out in the form of diamond. The diamond is usually found as loose crystals in alluvial deposits. The most important of these deposits are those of India and Brazil. The former deposits were known in very early times, and Golconda was the centre of the diamond trade of the antique world. At the present time the diamond production of India is insignificant. The Brazilian diamonds were discovered in 1728. The provinces of Minas Geraes and Bahia are the most productive. The diamonds are found in alluvial deposits derived from the materials brought down from the hills bordering the higher parts of the valleys. It is estimated that since the opening of the Brazilian mines they have yielded altogether three tons of diamonds. The output in 1902 was 40,000 carats. In Borneo diamonds are found with gold. The production in 1901 was 1,972 carats. Since the introduction of the South African supplies the production has fallen. The famous Borneo diamond, of 367 carats, known as the "Matan," from the territorial title of the Rajah to whom it belongs, has been thought to be the largest known, and was estimated to be worth £269,378. The

Dutch made very large offers of money and warlike material for it early in the 19th century, but they were always refused. The stone, it appears, was examined in 1868, and proved to be only a rock crystal with a specific gravity of 2.63, thus confirming doubts previously expressed as to its being really a diamond. About 95 per cent. of the world's supply of diamonds is produced in South Africa. The diamond mines of the Kimberley field have been described in papers read before the Society by Professor J. Tennant* in 1870, and by Mr. R. W. Murray† in 1880; and in 1893 I read a paper‡ describing a visit to the mines. Since then many changes have taken place, and a brief account of the development of the industry may not be out of place. The story of the accidental discovery of the diamond fields in 1867 has often been told. The first diggings were river washings, for the existence of diamonds away from the Vaal was not suspected, until, in 1870, garnets were discovered on a Boer farm, and diamonds were looked for. This caused the great rush to Kimberley. The mines were worked as deep, open quarries, the diggers working independently, and a system of aerial ropeways was developed, that made the mines look like a spider's web. In 1879, continued falls of rock from the sides of the excavations, and the constant influx of water, led to the idea of sinking shafts at the side of the quarry, and of reaching the diamond ground by underground galleries. As time went on, excessive competition reduced the price of diamonds to the lowest ebb, and Cecil Rhodes and others associated with him conceived the idea of amalgamating the various companies. The amalgamation was skilfully accomplished, and the De Beers Consolidated Mines, Ltd., acquired control of the diamond trade of the world, the cheque finally paid in 1889 for the shares in the Kimberley Central Company being the largest drawn up to that date. The five mines at Kimberley, the De Beers, Kimberley, Du Toitspan, Bultfontein, and Wesseltown, occur in a circle four and a-half miles in diameter. The deposits are evidently the result of the filling-in of extinct craters with volcanic mud from below. The matrix of the diamond, the blue ground, is a breccia composed of shale, basalt, and diorite cemented together by olivine rock. The weathered upper portion of the blue ground is known as yellow ground; and this is what was worked in the early days,

the blue ground being then thought to be bed-rock. In 1887, Mr. Gardner F. Williams introduced a system of mining in which all the blue ground is removed by overhand stoping from the rock wall farthest from the shaft, the broken surrounding rock being allowed to run in and fill up the stopes. The levels are 40 feet apart, with main levels, from which hoisting takes place, 320 feet apart. The main shaft at Kimberley is 2,160 feet deep.

The winning of the diamonds is an interesting process. The blue ground, deposited from trucks conveyed by endless chain haulage, is harrowed as it lies exposed to the disintegrating action of the sun and rain, on the depositing floors. These have a hard and level surface, and at De Beers cover an area of about two square miles. The blue ground, spread to a thickness of nine inches, lies exposed for about six months before it is thoroughly disintegrated. Even at the end of that time, there is some 14 per cent. of the material that is not acted on, being so hard that it has to be crushed. When the disintegration is complete, the material is hauled to the washing machines, where it is raised by a lift, and passed through a revolving cylindrical screen with $1\frac{1}{4}$ inch holes. The lumps pass out for further treatment, whilst the pulverised blue ground passes into shallow annular pans in which are mounted revolving toothed arms. The diamonds and heavier matter pass to the outside, whilst the lighter waste material flowing towards the centre, is discharged. The entire gear is driven by electric motors. The concentrates are conveyed in locked trucks to the pulsators which are similar to the jigging machines used in ore-dressing. The heavy material obtained, containing the diamonds was, until recently, taken to the sorting tables, the sorting being conducted first when wet by skilled workmen, and again when dry by native convicts. This tedious procedure was done away with by Mr. Kirsten, who invented the automatic diamond sorter termed the "greaser," in which a table built up of five steps covered with a coating of thick grease is vibrated rapidly as the concentrates are allowed to drop on to the top step gradually. The diamonds adhere, whilst the garnets, zircons, mica, magnetite, pyrites, and other minerals are washed off. The diamonds are boiled in caustic soda to clean them. Formerly, out of 192,000 cubic feet of blue ground washed daily at De Beers and Kimberley mines, 160 cubic feet had to be sorted by hand. Now, with the appli-

* *Journal of the Society of Arts*, vol. 19, p. 15.

† *Ibid.*, vol. 29, p. 370.

‡ *Ibid.*, vol. 41, p. 168.

cation of the greaser, only 1 cubic foot reaches the hand sorting tables. The separated diamonds are taken to the general offices, where they are cleaned by boiling in acid, and sorted for sale. In order to prevent illicit traffic in diamonds and to provide for 12,000 natives employed at the mines, the management has had difficult problems to deal with, which have been solved by keeping the native miners within compounds during

abundant supply of water provided, roomy washhouses, and a large open swimming bath in the centre of the square; and wash-tanks are everywhere. The compound-square presents an interesting spectacle; hundreds of natives of every shade of black and bronze are scattered about. The stores are stocked with every variety of provisions and necessities, fresh bread daily, mealies, flour, sardines, potted meats, eggs, oranges, bacon,

FIG. 13.



MALACCA DIAMOND MINE, INVERELL.

the period of the agreement with the company. These compounds, of which there are twelve, consist of rows of iron buildings placed along the sides of a large square, which is surrounded by a 10 foot wall. The largest one at the De Beers mine covers an area of about five acres, and affords accommodation for 2,000 natives. The houses which the natives occupy are clean, lofty, airy tenements, with sleeping bunks arranged somewhat as in large steamers. Sanitary regulations are strictly enforced; and an

pipes and cigars, and an abundance of fresh meat. The Kaffirs buy their own provisions and do their own cooking, members of the same tribe frequently clubbing together for this purpose. The compound is also provided with a hospital, dispensary, church, and school.

Next in importance to the four great mines of the De Beers Company, to which reference has been made, is the mine at Wesselton, which was not discovered until 1890. It is worked as an open quarry, and yields clear stones of irregular shape. The extent of the operations of

the De Beers Company is clearly shown in the statistics of production for the year ending June 30th, 1902, the output of diamonds having been 2,025,224 carats from blue ground, 202,830 carats from tailings, and 18,728 carats from old concentrates. At De Beers and Kimberley, 2,062,459 loads of blue ground were hoisted, yielding 1,491,012 carats of diamond valued at £3,465,050. The number of carats yielded per load was 0·76, the value per carat being

the Transvaal, some 25 miles to the east of Pretoria. The production of these deposits in the year 1902-3 was 33,572 carats, valued at £46,358. In August, 1903, alone, at the three mines in the Pretoria district, 14,230 loads were washed, yielding 16,135 carats, valued at £21,676, the average yield being 1·134 carat per load. The following are the principal mining companies in which British capital is invested :—

Name of Company.	Capital issued.	Registered.	Situation of mines.
Brazilian Diamond Field Corporation, Ltd.....	8,870	1902	Bahia.
Brazilian Diamond and Exploration Co., Ltd.	60,000	1902	Minas Geraes.
Consolidated Bultfontein Mine, Ltd.	721,500	1888	Kimberley, leased to De Beers.
Diamond Exploration and Finance Syndicate, Ltd.	22,500	1902	
Elandsdrift Diamond Estates	300,000	1901	Barkly West, Cape Colony.
Frank Smith Diamond.....	250,000	1900	" " " "
Griqualand West Diamond Mining Co., Ltd.	1,057,000	1881	Kimberley, leased to De Beers.
Inverell Diamond Fields, Ltd.	381,307	1900	Mayo, N.S.W.
Kamfersdam Mines, Ltd.	300,060	1896	Cape Colony.
Koffyfontein Mines, Ltd.	220,427	1893	Jacobsdaal, O.R.C.
Lace Diamond Mining Co., Ltd.	250,000	1899	Kroonstad, O.R.C.
Malacca Diamond Mines, Ltd.	105,007	1900	Hardinge, N.S.W.
New Jagersfontein Mining and Exploration Co., Ltd.	1,000,000	1887	Orange River Colony.
New St. Augustine Diamond Mining Co., Ltd.	81,361	1902	Griqualand West.
Orange Free State and Transvaal Diamond Mines, Ltd.	550,000	1894	Kaal Vallei, near Ventersburg.
Otto's Kopje Diamond Mines, Ltd.	488,660	1900	Kimberley.

35s. 6d. The cost of production per load was 8s. 5½d. The Premier mine at Wesseltown produced 1,932,140 loads yielding 561,990 carats valued at £941,300. The number of carats per load was 0·30, the value per carat being 33s. 6d. The cost of production per load was 3s. 5d.

In the early days, a good deal of the waste from the mines was used for making up the streets of Kimberley, and, at the present time, the streets are being washed for diamonds, with very remunerative results. Outside Kimberley there are several diamond mines, but none have attained the success of the Kimberley mines. At Jagersfontein, where diamonds were discovered in 1870, the stones are of better quality than De Beers, but the average yield is much less. On the Vaal river, where river washings were extensively carried on; the deposit is similar in composition to that of Kimberley, and is worked as a quarry by two companies. The mineral is screened, and washed and treated on greasers, as at De Beers. The stones are small but of good colour. The most recent development of the South African diamond industry, has been the wonderful discoveries of diamond deposits in

The existence of diamonds and other gems in New South Wales was recorded as early as 1851, but no systematic attempts to work the deposits were made until 1872, and little success attended the industry until 1890. The diamonds occur in the Inverell and other districts in old Tertiary river drifts. The diamonds are harder and whiter than the South African ones. The majority of diamonds obtained weigh from 1-6th to 1-5th carat, while the largest vary from 2 to 3 carats. The number obtained per load varies very greatly; the Round Mountain Company at Cope's Creek, in the Inverell district, washed 722 loads for 2,685 carats in 1886, obtaining from six loads the exceptional yield of 1,080 diamonds, weighing 296 carats. In 1902, the Inverell Diamond Fields, Ltd., obtained 4,538 carats from 4,640 loads. The total output of New South Wales was 11,995 carats, valued at £1,1326, and the Malacca Diamond Mines, Ltd. (Fig. 13) are now giving regular returns of 1½ carats of diamonds to the load. Another source of diamond supply is British Guiana, where, in 1901 there were produced 91,286 diamonds, weighing 8,227 carats.

Although known in ancient times, diamonds were for centuries but little used as ornaments. The practice of roughly cutting diamonds is of great antiquity, but it was not until 1456 that Louis van Berghem, of Bruges, discovered the art of cutting into facets. The double-cut brilliant, now the usual form, was introduced by Vincenti Peruggi, of Venice, at the end of the 17th century. The centre of the diamond-cutting industry is Amsterdam, where some 12,000 workmen are employed. Of late years Amsterdam has lost the monopoly it formerly possessed, and more diamonds are cut in New York, London, and Antwerp. The finest stones are those from India. The oldest known and largest, the Great Mogul, was seen by Tavernier in Delhi, in 1665. It was subsequently lost. Its weight was 280 carats, and the uncut stone must have weighed 787 carats. The Orloff diamond (193 carats), mounted in the Russian Imperial sceptre, and the Kohinoor (originally $186\frac{1}{16}$ carats) are also of Indian origin, and similar in form. The latter was recut in 1852 with a reduction in weight to $106\frac{1}{8}$ carats. The most beautiful cut brilliant is the Regent or Pitt diamond in the possession of the French Government, which was recut in London in 1717, and thereby reduced in weight from 410 carats to $136\frac{3}{4}$. The Florentine diamond now in the possession of the Emperor of Austria is $133\frac{1}{2}$ carats in weight and cut in the usual manner. The Nassak diamond, $89\frac{3}{4}$ carats, is of an irregular triangular shape. The Pasha of Egypt diamond weighs 40 carats. Every year we hear of new discoveries in South Africa of diamonds of remarkable size. The largest, the Excelsior, was found in 1893 at Jagersfontein, and weighed $971\frac{3}{4}$ carats. The yellowish De Beers diamond, $428\frac{1}{2}$ carats, gave when cut a brilliant of $288\frac{1}{2}$ carats. Of coloured diamonds, the Hope blue diamond ($44\frac{1}{2}$ carats) and the pale green diamond (40 carats) at Dresden are the most celebrated. The quantity of diamonds the world has produced up to the end of 1901 may be estimated as follows:—

	Carats.
Russia	25
North America.....	110
British Guiana	20,000
New South Wales	110,000
Borneo and India.....	300,000
Brazil	15,000,000
South Africa	68,000,000
	83,420,135

or about 17 tons.

Corundum Gems.—India is specially rich in corundum. A large number of localities at which it occurs are mentioned in Mr. T. H. Holland's monograph published by the Geological Survey of India. There are large deposits of the common form of this mineral, emery; and the most highly prized specimens of its transparent red variety, the ruby, have been obtained from Burma, whilst the mines of Kashmir are noted for the size and transparency of the blue variety, the sapphire. Until recently nearly all the known occurrences of corundum were in detrital material. Mr. C. Barrington Brown was the first to prove the existence of the ruby *in situ* in crystalline limestone, and in conjunction with Professor Judd he has published a masterly memoir on the subject in the "Philosophical Transactions of the Royal Society." The most important locality is near Mogok, in Upper Burma. The rubies occur in a clayey mass, an alteration product of a coarsely granular marble. Sapphire, spinel, and tourmaline are also met with. This marble appears to have been derived by contact metamorphism from a dolomite limestone of Upper Carboniferous age. Such limestone still stands unaltered in many places, and in others has been altered into marble by up-bursts of eruptive rock. The clay containing the rubies lies at the side of valleys and fills wide cavities. The stones found are much worn and corroded on the surface. The Burma Ruby Mines Co., Ltd., founded in 1889 with a capital of £150,000, is now, after many difficulties, obtaining very satisfactory results. In the year ending February 28th, 1902, a dividend of $17\frac{1}{2}$ per cent. was paid. During the year 1901 the Company washed 947,444 loads of gem earth at a cost of 10·29d. per load. The production included 210,784 carats of rubies, 9,786 carats of sapphires, and 10,241 carats of spinel. The methods of mining for the ruby in Burma are suited to the three modes of its occurrence in the limestone, in hill detrital material, and in the alluvial deposits in the valleys. In the quarries blasting is unsuitable as it injures the gem stones. The dirt is raised by endless ropes from quarries 50 feet deep. Stones of greater weight than four carats are of such exceptional occurrence that they command fancy prices. The largest known were brought from Burma in 1875 and weighed 37 and 47 carats respectively. They are said to have been sold for £10,000 and £20,000. English cut sapphires under one

carat vary in price from £4 to £12, but the value does not, like that of the ruby, increase enormously in proportion to its size. Mr. G. S. Streeter,* who described the Burma ruby mines, mentions an Indian sapphire weighing originally 225 carats, and worth £7,000 to £8,000. Small rubies and sapphires are largely used for bearings in watches. In the United States alone about 1,200,000 watches with jewelled works are manufactured annually, requiring 12,000,000 jewels, of which 5,000,000 are ruby and sapphire, the remainder being garnets. Rubies and sapphires were obtained to the value of about £3,701 in 1902 from shallow diggings in Siam. Small quantities of sapphires are also obtained from alluvial workings in Ceylon. At Anakie, Queensland, in 1902, some £5,000 worth of sapphires were raised. Sapphire, corundum, and emery are of frequent occurrence in the United States. In Montana sapphires are largely mined; they occur in an eruptive dyke in limestone. The various localities are enumerated by Mr. J. H. Pratt in a recent report to the United States Geological Survey. Sapphires are not in great demand for the moment chiefly because they do not appear to advantage in artificial light, but seem dark and dull. In experimenting on the action of various rays on rubies, Chaumet ascertained that the Siamese stones are of scarcely appreciable fluorescence under violet light, while all the valuable Burmese rubies are intensely fluorescent.

Emery, the common form of corundum, is found in large quantities in the Island of Naxos, and the mines are the property of the Greek Government. The Naxos emery is superior to that of Asia Minor owing to its great density, and the greater fineness and hardness of its grain. It fetches 112 to 115 francs a ton. The world's consumption of emery is 25,000 tons annually, of which Asia Minor supplies some 18,000 tons, valued at £53,000; Canada 388 tons, valued at £10,914; and Naxos 6,328 tons, valued at £26,830.

Owing to the great value of the ruby, other stones are frequently described as such in commerce, notably the deep red spinel or the pale rose tinted Balas ruby, which is composed of alumina and magnesia, coloured by iron or chromium. When of fine colour it is a valuable stone. Spinel is derived chiefly from Ceylon, where they are found in alluvial deposits. Red tourmaline is sold as Siberian ruby, and

garnet is sometimes passed off as ruby. Topaz of a pink colour is sold as Brazilian ruby. Similarly cyanite, a silicate of alumina, found in Brazil and India in blue crystals, and cordierite, found in blue crystals in Ceylon, and characterised by its dichroism, are sometimes sold as sapphires.

Emerald.—Emerald is rarely found in detrital material, but usually *in situ* in mica schist or limestone. Beryl, aquamarine, and emerald are silicates of aluminium and glucinum. The deep green emeralds have now become scarce and have greatly increased in public favour. The beryl is fairly abundant. The less transparent stones are of no great value, but occur in masses of large dimensions in many localities in the United States; the finest are from Siberia, Madras, and Brazil. The celebrated emerald locality in Norway was recently taken up by the Norwegian and General Exploitation Company, Ltd. (capital issued £75,000). Quantities of beryl have been found, but no valuable emeralds.

In the Republic of Colombia the Muzo Mine, recently offered for sale, has been famous since the year 1555, for the production of the finest emeralds of the world. The mode of working is similar to that adopted in Europe in large quarries. The top soil is removed by washing until the slate rock is left bare, this being cut away by means of long bars, and with the aid of blasting. The stones are found chiefly in pockets, but occasionally some are found isolated from the veins. The large amount of *débris* resulting, is carried away by means of discharges of water from reservoirs at an elevation above the workings, by means of syphons. The stones, after extraction, are classified into six qualities. The greater quantity are forwarded to British India to be cut, and afterwards the better qualities return to the markets of Europe for sale. The decrease in the world's output of emeralds during the past few years has been such as to cause grave concern among the precious stone dealers. Unless new mines are discovered soon, it is not unlikely that emeralds will become the rarest precious stones in the world. As the condition of the market is now, they are worth (in stones larger than five carats) from two to ten times as much as diamonds. Several stones now in the hands of New York dealers are worth from £3,000 to £10,000 apiece. They range from ten to thirty carats in size, and are not free from imperfections.

There are several precious stones of a green

* *Journal of the Society of Arts*, vol. 37, p. 266.

colour that are sometimes sold as emeralds. The more important of these is chrysolite or periodot, a silicate of magnesia coloured green by iron. It is of a soft green colour. Fine examples exist in various church treasures collected probably during the Crusades, but the original locality of these gems is unknown. The common form of the mineral (olivine) is abundant in eruptive rocks. Hiddenite, a silicate of aluminium and lithium, found in North Carolina, is much esteemed in America, under the name of lithium emerald. Tourmaline, when of a dark green colour is sold as Brazilian emerald. It is, however, easily recognised by its dichroism.

Opal.—Opal consists of hydrated silica. It owes its peculiar play of colour to the numerous irregular fissures traversing it, which contain laminae that reflect the rays of different colours. The finest opals formerly came from Hungary, Mexico, and Honduras, where they occur in igneous rocks. In Hungary, the opal mines at Dubnik are mined by the State. The opal occurs lining open fissures in pyroxene-andesite. The opals are sorted into four classes. The undertaking affords employment to 140 workmen, and yields about 12,000 carats annually. In 1889 a rich vein was found, and the yield was 28,000 carats. Australia is now the chief source of production of precious opal. The rich opal fields of White Cliffs, New South Wales, was discovered by a mere accident, in 1889, and since then opal mining has become an important industry. The mineral occurs in seams in Cretaceous deposits, and varies in value from very little up to £25 an ounce, the unit of purchase in the rough. A specimen recently found, weighing 13 lbs., was a solid mass of gems. The value of the opals raised in New South Wales in 1902 was £140,000. In Queensland, the workings cover a wide district, having been traced from Eulo, in the Gunnamulla district, about 150 miles north of Bourke, in New South Wales, for some 500 miles in a north-westerly direction as far as Winton, in the county of Ayrshire. The precious opals met with occur here and there in patches in upper Cretaceous sandstones and clays. In places the mineral is found scattered over the surface, being set free by denudation, but such occurrences furnish little evidence of precious opal below. The average depth of the shafts is 14 feet, and the deepest is about 65 feet. The great difficulty in the progress of the industry is the scarcity of water, the annual output being dependent on the rainfall. The value of the Queensland production

in 1902 was £7,000. Mr. G. F. Kuntz declares that more opals are sold in a year than were sold in fifty years before the Australian mines were opened. The beauty united to the low price and abundance of much of the opal won makes it available for all kinds of decorative effects in the jeweller's art. Of precious opal, the finest, from Czerwenitz, Hungary, is in the celebrated bouquet of gems presented by the Empress Maria Theresa to her Consort. It is now in the Vienna museum. It weighs 594 grammes and is valued at £160,000. Central America and Mexico are also said to be producers, and occurrences have been noted in Tasmania. The most important point in buying opals is colour. Red is in the keenest demand, or red in combination with yellow, blue, and green. Pattern is a secondary consideration in valuing the stone. Harlequin is the rarest of all, and when the colour squares of red, yellow, blue and green are regular and distinct, its beauty is remarkable. The flash opal, though not so rare as the harlequin, is scarcely less attractive, particularly when its colour veins are of the true ruby or pigeon's blood hue.

Turquoise.—Turquoise is of a bright blue to greenish blue colour but opaque. The most valuable stones are azure blue with a resinous lustre, taking a high polish. The colour gradually fades on exposure to sunlight. The gem was appreciated even in the time of Pliny. It is a phosphate and hydrate of alumina coloured by copper. It occurs in small reniform masses in Persia and Arabia. The celebrated turquoise mines of Persia are situated in a mountainous region 6,000 feet above sea level. They employ 1,500 persons. Many of the mines are mere burrows. Turquoise mining is now active in the United States where the gem is in great favour. Turquoise has also been found in the Murchison district, Western Australia, and deposits are being worked in Egypt. Odonatolite, frequently sold as an inferior turquoise, is fossil bone coloured by copper.

Garnet.—Gems of the garnet group are obtained in great abundance. The varieties most esteemed are the violet-coloured almandine or precious garnet, the brownish-red or carbuncle, usually cut *en cabochon*, the yellowish-brown cinnamon stone, and the pyrope or Bohemian garnet. The hilly Cretaceous district of North-East Bohemia for many years supplied the world's market with garnets, but the South African garnets, a by-product in diamond mining, have caused the abandonment of nearly all the Bohemian

mines except the extensive open-workings at Podseditz, where the Pleistocene drift containing the garnets is nine feet or more in thickness, and lies a couple of feet below the surface. Gem garnets of great beauty have been discovered in the Cowee valley, in North Carolina, the yield in 1901 being 200,000 carats, valued at £4,000 after cutting. In the same year the United States produced 4,444 tons of garnets, for abrasive purposes, valued at £31,600.

Other Precious Stones.—Chrysoberyl is a beautiful greenish-yellow precious stone of great rarity. It is the third hardest in the series and consists of alumina and glucina. It occurs in the form of rolled pebbles in Brazil and Russia. Cut *en cabochon*, the less transparent specimens give one of the stones termed by jewellers "cat's eye." Zircon, hyacinth, and the green-coloured jargon, are silicates of zirconia. They are the heaviest of all precious stones, and occur embedded in granite, basalt, and lava, and in alluvial beds in Ceylon. The topaz is a fluosilicate of alumina, usually of a yellowish-brown colour, sometimes pale blue. The best come from Brazil. Topaz is found in veins in granite and in the form of rolled pebbles. The transparent moonstone, mined in the Kandy district of Ceylon, the apple-green amazon stone, the Norwegian sun-stone, and the iridescent labradorite, are forms of felspar owing their value as ornamental stones to certain effects of light.

Ornamental Stones.—Of the pure siliceous minerals used as ornamental stones, there are the crystalline transparent forms of silica, the pure colourless rock-crystal, the purple amethyst, the yellow citrine, the brown cairngorm, and the pink rose-quartz, together with the amorphous, translucent, or opaque forms, the white chalcedony, the red carnelian, the deep reddish-brown sard, the green chrysoprase, and the olive-green plasma. The banded variety of chalcedony is agate; when the bands of colour lie in even planes it is termed onyx; or, with alternating bands of red and white chalcedony, sardonyx. For purposes of ornament, the colour of most of these stones is frequently modified by staining, a process practised even in the time of Pliny. In moss agate, and mocha stone, the moss-like markings are due to manganese oxide. Of the opaque variety, jasper, there are several forms, ribbon jasper, with the colours in stripes, Egyptian jasper found in rolled pebbles, with the brown colours in concentric

zones, and bloodstone or heliotrope, a jasper of deep green colour, with blood-red spots. Quartz, either fibrous or with some enclosed fibrous body, constitutes a variety of cat's-eye, which has a peculiar lustre. The so-called crocidolite, which first came to Europe from Cape Colony in 1870, is a fibrous form of quartz of rich brown colour. It was formerly exceedingly rare, but is now obtained in considerable quantities. In 1901, the production was 3 tons valued at £150. The brilliantly spangled aventurine is quartz with disseminated particles of mica.

Brazil is the principal source of supply of amethysts. Recently, an immense amygdaloidal cavity lined with amethyst, was found, surpassing anything of the kind previously known. It measured 33 feet in length, 16½ feet in width, and 10 feet in height, and weighed about 35 tons. It was put together to form the Amethyst grotto that was one of the attractions of the Düsseldorf Exhibition of 1902.

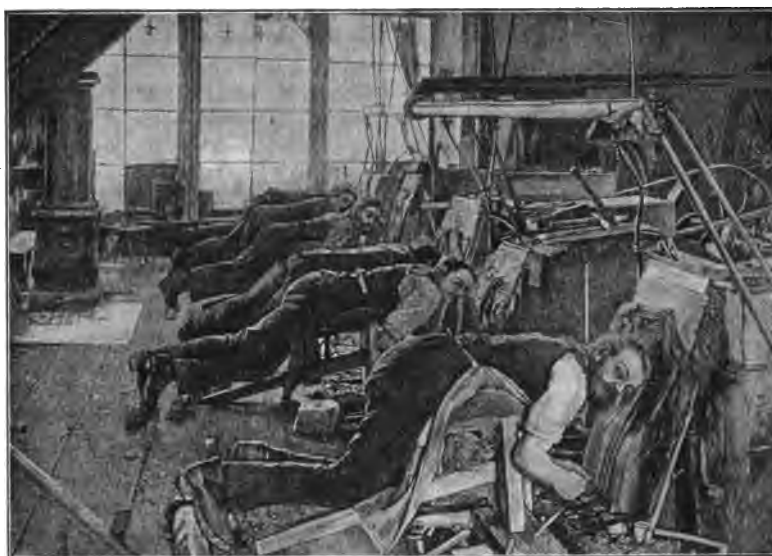
The centre of the agate cutting industry is at Oberstein in Germany, where the river Idar in its descent to the Nahe presents a succession of falls through a distance of 24 miles and supplies power for some 60 polishing works. Precious and semi-precious stones are received for polishing from all parts of the world, and the development of the industry has necessitated the use of steam-engines and electric motors in place of the water power originally employed. The agates are ground on sandstone wheels: the workman lying horizontally presses the agate against the grindstone, obtaining purchase by pressing his feet against a block fixed to the floor. (Fig. 14). An important branch of the industry is the preparation of blanks for cutting onyx cameos in Paris and Italy. The cameos are usually cut on stones that have layers of different colours, so that the design appears in white on a red, brown, or black ground.

The finest example of sardonyx cameo is in His Majesty's collection at Windsor Castle. It measures 7½ by 5½ inches, and is cut upon a rich Oriental sardonyx of four strata. It is a contemporary portrait of the Emperor Claudius. The ground is in the dark brown stratum, the laurel wreath and front of the cuirass in the honey-brown, and the head and hair in the white. The whole is surrounded by a raised border enriched with moulding cut in the thickness of the stone. The most important cameo in existence is the "Gemma Augustea" (Fig. 15) in the Art Historical Museum in Vienna. It is cut upon sardonyx of two layers,

the figures being cut in the bluish-white layer, while the dark forms the background. It measures $7\frac{1}{4}$ by $8\frac{3}{4}$ inches. The design represents Tiberius before his splendid triumph, 12 B.C., descending from his chariot, with Germanicus standing at his side, to present himself to his father Augustus who is seated with the emblems of Jupiter, by the side of the goddess Rome. The figures at the base represent captive Germans, and Roman soldiers erecting a trophy. The process of cameo-cutting, and some of the best examples, have been described by Mr. J. B. Marsh* and by

nephrite forms narrow veins in serpentine. In East Turkestan it was worked by fire-setting, and it occurs in considerable quantities in Siberia. Greyish-green jade is known *in situ* on Monte Viso in Italy, and in Burma. The Maoris still use nephrite for tools, the mineral having recently been discovered for the first time *in situ* in New Zealand, in serpentine, on D'Urville Island. Large bodies of jade-stone are found near Hsu-Yen, on the river Ta-Yang, that empties in the bay of Corea. In many localities these minerals have been found only in worked pieces. In Mexico and Central

FIG. 14.



AGATE POLISHING. (Professor M. Bauer).

Mr. C. Davenport.† The celebrated so-called Mexican onyx, the occurrence of which has been described by Mr. W. Eassie,‡ is in reality an aragonite stalagmite. This rich ornamental stone is largely quarried.

Jade.—Under the name of jade are included two minerals, nephrite and jadeite, closely similar in appearance and properties. It was found by Damour, in 1865, that the former is a silicate of alumina, lime, and magnesia, and the latter a silicate of alumina and soda. These tough minerals are mostly found in detrital deposits. Even now but a few localities are known where they occur *in situ*. In Europe the only one is at Jordansmühl in Silesia, where

America jadeite only is found, not nephrite whilst amongst the jades of the north-west coast of America, Siberia, and New Zealand, jadeite has not been recognised. The most remarkable specimen of jadeite known is a Mexican adze with a grotesque human figure carved on its face. It weighs 229 ozs., and is now in the New York Museum. It has been described by Mr. G. F. Kunz, who, in a recent paper, discusses the question, whence the jade so highly prized in Mexico and Central America by the primitive people was obtained. The problem is of great interest to archeologists, and its solution might give to the world a beautiful ornamental stone.

Amber.—Since the times of the Etruscans, the Greeks, and the Romans, amber has been obtained from East Prussia, which is still the

* *Journal of the Society of Arts*, vol. 35, p. 147.

† *Ibid*, vol. 49, p. 141.

‡ *Ibid*, vol. 34, p. 503.

chief source of supply. The Prussian Government has a monopoly of the industry. The fossil resin was first found washed up by the water from a submarine bed of Tertiary age, extending along the shores of the Baltic to Cromer on the Norfolk coast. This sea amber is characterised by the fact that it has no weathered exterior. After storms, large quantities are washed ashore and collected. It is also collected in nets, and since 1869 divers have been successfully employed by the Königsberg firm of Stantien and Becker, to collect amber from the bottom of the sea and to dig it out. More than twenty large steam dredgers are in use raising the material from a depth of 7 to 11 yards. Quarries are also worked near the sea-shore, and every year

FIG. 15.



GEMMA AUGUSTEA.

a large proportion of the amber production is obtained in this way. The greyish-blue sandy clay, known as blue earth, containing the amber, is opened up by quarrying and by ordinary mining. The principal workings are about mid-way between Memel and Dantzic, the largest mine being at Palmnicken, where the blue earth is 16 feet thick. The mine galleries have a total length of 150 miles, and the annual yield of amber is about 200 tons. The amber is separated from the enclosing earth by washing on coarse screens with a powerful jet of water. The cleaned amber is finally sent to Königsberg, where it is sorted for the market into nearly a hundred different varieties. The flat pieces of amber are turned for smokers' requisites, and the round pieces cut in facets or worked into beads for bracelets and necklaces. The pieces of amber can be softened in boiling

linseed oil, and the cloudy specimens rendered clear. The small impure amber is used for the manufacture of varnish. The total annual consumption of the world of crude amber represents a value of about £150,000. Many imitations of amber are manufactured, and compressed amber, or ambroid, made by compressing small pieces at great pressure and high temperature, is largely utilised. The income derived by the Prussian Government from the amber industry amounted in 1811 to £1,100 annually, and rose in 1895 to £35,500. The mineral is State property, but, as a matter of fact, the working and sale was leased to the firm of Stantien and Becker for many years. On July 1st, 1899, the Prussian Government purchased the whole of the works of this firm, and started to mine and trade on the State account. The purchase price was £487,500. Details of the various uses of amber are given in a paper read by Mr. P. L. Simmonds.* Amber is obtained in irregular masses, usually of small size. A single enormous piece of amber, weighing nearly 7 lbs., was found a few years ago, by some fishermen at Langlutjensand. The largest piece on record, 18 lbs., is in the Berlin Museum.

Other Ornamental Stones.—Among other ornamental stones are the comparatively soft green malachite (carbonate of copper) and the azure blue lapis lazuli, a complex combination of silicate and sulphate, which was formerly powdered and washed to make the ultramarine of the artist. The richer varieties are used in mosaic, and for costly vases and jewellery. Steatite, or soap-stone, is used by the Chinese for carving figures. Jet, a variety of lignite, the Gagates of the ancients, is largely used for mourning ornaments. In England, jet mining is not pursued as a regular occupation, in the cliffs near Whitby a little burrowing is done in stormy weather when agricultural work is difficult. The manufacture of Whitby jet was described in 1873 by Mr. J. A. Bower.† Of late years the trade has died out. Comprehensive descriptions of the different precious and ornamental stones will be found in Mr. G. F. Kunz's well-known work on the precious stones of the United States, and in Professor Max Bauer's "*Edelsteinkunde*," of which an English translation by Mr. L. J. Spencer is announced.

The Rare Earths.—In the early days of chemistry the term "earth" was applied to certain substances now known to be oxides of

* *Journal of the Society of Arts*, vol. 18, p. 180.

† *Ibid.*, vol. 22, p. 89.

metals, which were distinguished by being infusible at a high temperature. On account of the scarcity and infusibility of the oxides of the cerium and yttrium groups, the old term is still made use of, and they are known as the "rare earths." From the discovery of yttria by Gadolin in 1784, until recent years, these rare earths were solely of chemical interest. When, however, the system of incandescent gas lighting, invented by Auer von Welsbach, came before the public in 1886, the rare earths at once acquired industrial importance, and eager search was made for minerals containing them in all parts of the globe. Briefly described, Welsbach's process consists of impregnating a cotton tube with a solution of the nitrates of the rare earths, whilst the upper end is further impregnated with a strengthening solution. The chief sources of the rare earths are the minerals allanite, orthite, gadolinite, xenotime, euxenite, yttrantalite, fergusonite, tyrite, cerite, and zircon. Although the standard works on mineralogy give a long list of localities at which specimens of these rare materials have been found, the supply is very limited, and they are in consequence very expensive. Moreover, they do not contain appreciable quantities of the most active element for incandescent gas lighting purposes, thoria. The chief source of thoria is monazite, a mineral occurring in large quantities in Brazil, Norway, the Ural, Carolina, and Canada. Monazite is an anhydrous phosphate of the rare earths, cerium, lathanium, and thorium. It was first discovered in 1823, and it was subsequently found to be identical with numerous new minerals discovered in various localities, and receiving various names. The name that has survived was given to it by Breithaupt, in 1829, from the Greek verb, meaning to live alone, owing to the fact that at Mount Ilmen, in Siberia, it was met with in solitary tabular prisms. The translucent crystals are of a red or yellow colour, with a hardness nearly equal to that of felspar, and a specific gravity of 4.6 to 5.3. They vary in size from microscopic dimensions to 5 in. in length, in the case of those found in Amelia Country, Virginia. Irregular masses of monazite showing crystalline structure, and weighing 15 to 20 lbs., and rounded masses weighing 12 lbs., have been found at the mica mine of Villeneuve, in Quebec. The mineral contains 20 to 29 per cent. of phosphoric acid, 28 to 37 per cent. of ceria, 14 to 31 per cent. of lathana, 0 to 1.8 per cent. of yttria, and

2 to 18 per cent. of thoria. Monazite, or its varieties, is met with in many places. It usually occurs in granite. These deposits, however, have chiefly a mineralogical interest. Those of commercial value represent the product of the decomposition and disintegration of rocks that originally contained monazite. The first monazite sands to be utilised were obtained by the eminent mineralogist, Mr. W. E. Hidden, in considerable quantity in 1879, in the gold placers of Carolina, in association with platinum. In 1884, Hidden succeeded in inducing the Welsbach Light Company to experiment with monazite, with a view to extracting from it the rare earths it contains, and to substituting thoria for zirconia in the manufacture of the mantles for incandescent gas lighting. The Brazilian deposits occur as beach sea sands, and their concentration has been effected by the action of the waves. In the pegmatite dykes of southern Norway, monazite occurs in large crystals. In the United States the workable deposits of monazite sands are confined to Carolina, and cover an area of 1,600 to 2,000 square miles. Their thickness varies from one foot to two feet, and their monazite contents are very variable, ranging from an infinitesimal proportion up to one to two per cent. The mining of monazite consists merely in washing the sands in sluice boxes, similar to those employed in alluvial gold mining. The sluice boxes measure 8 feet in length, 20 inches in width, and 20 inches in depth. Two men work at a box, one charging the gravel on a perforated plate at the upper end, and the other working the contents up and down with a fork or perforated shovel, so as to cause the lighter sands to float off. The boxes are cleaned out at the end of the day's work. Magnetite, if present, is eliminated from the dried sand by treatment with a large magnet. Many of the heavy minerals, such as zircon, rutile, corundum, garnet, &c., can be completely eliminated. A cleaned sand containing 65 to 70 per cent. of monazite is considered of good quality. According to Mr. H. B. C. Nitze, from 20 to 35 lbs. of cleaned monazite sand per man is a good day's work. The cost of labour is 3s. per day. In South Carolina, better methods of mining and cleaning are used, and a richer product is obtained. Various classes of sand are produced, the best containing 85 per cent. of monazite. The South Carolina production, however, represents only a small proportion of the output of the United States, for the mines are much less important than those of North

Carolina. In some exceptional cases it is possible to extract with profit the monazite from the containing rocks *in situ*. For example, in Cleveland County, North Carolina, at the Phifer Mine, hillside mining is resorted to in the case of a micaceous gneiss, in which crystals of monazite occur. The production of monazite is very irregular, but at the present time the market easily absorbs all that is produced. The highest price recorded was in 1887, when it was 1s. per lb., but it fell suddenly to 2½d. At the present time prices vary from 2d. to 4d. per lb., with a proportion of thorium varying from 2 to 6 per cent. The production of the United States in 1901 was 748,736 lbs., valued at £11,852. The production of Brazil was 1,643 tons, valued at £23,937. The production in Australia, Siberia, and Norway is considerably less.

Conclusion.—I regret that owing to the difficulty of showing specimens to a large audience, it has been found necessary to confine the illustrations of these lectures to

lantern photographs. Specimens of the various minerals to which reference has been made can be examined in many public collections, notably at the Natural History Museum and the Museum of Practical Geology in London, in the United States National Museum at Washington, and in the Natural History Museum in Vienna. A visit to the mineralogical collections of the museums mentioned is rendered specially instructive by the scholarly guides that have been prepared by Mr. L. Fletcher, by Mr. F. W. Rudler, by Mr. G. P. Merrill, and by the Ritter von Hauer, respectively. Well arranged collections of Indian and Colonial mineral products may be studied at the Imperial Institute, while for the St. Louis Exhibition of 1904 the Home Office authorities are preparing a representative collection illustrating the mineral resources of the United Kingdom, on the same lines as that formed by the Council of the Society of Arts for the Chicago Exhibition of 1893.

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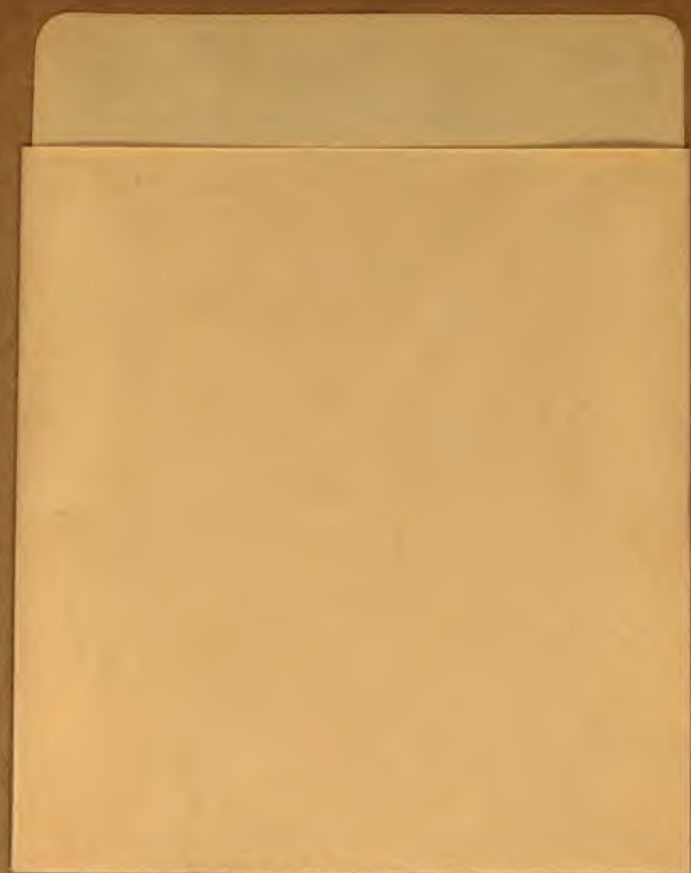
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